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GLACIAL STUDIES IN GREENLAND.

DURING the past summer it was the privilege of the writer to visit Greenland as geologist to the Peary Auxiliary Expedition, and to study some of the glaciers of its middle and northern portions. A sketch of the observations made, so far as they are deemed worthy of publication, and a discussion of their bearings will be attempted in a series of articles to which this is introductory. While the itinerary form, which is quite the fashion in Arctic literature, will not be followed, an outline of the journey may perhaps give some glimpses of Arctic conditions that will be of interest, and possibly of service, to those who have occasion to consider the ways and means of studying in the far north. Incidentally, it will be convenient to introduce some miscellaneous observations made on the way, which would not readily find place in a formal description or discussion of the glaciers.

Provision was made for the expedition by Lieutenant Robert E. Peary, Civil Engineer, U. S. N., last year, before leaving the United States on his third trip to Greenland. Its primary object was to communicate with his party, with the alternative purpose of supplementing its outfit, if necessary, should it remain, and of offering it a means of return, should its work be finished. A collateral object was to do such independent scientific work in geographical, biological, ethnological, and glacial lines as time and conditions might permit.

The expedition was organized and directed by Mr. Henry G. Bryant, Secretary of the Geographical Club of Philadelphia, whose

exploration of the Grand River of Labrador is well known. The party was limited to seven, the six additional members being: Professor William Libbey, Jr., of Princeton University, geographer; Dr. Axel Ohlin, of Sweden, zoölogist; H. L. Bridgman, of Brooklyn, historian; Emil Diebitsch, of Port Royal, S. C., civil engineer; Dr. H. Emerson Wetherell, of Philadelphia, surgeon; and the writer. It was arranged that on reaching Inglefield Gulf my work might be conducted independently of the rest of the party, who proposed to make such examination of the coast of Ellesmere Land and Jones Sound as the condition of the ice would permit.

The party assembled at Brooklyn on June 20th, and took passage for St. Johns, Newfoundland, on the regular coasting steamer, Portia, of the Red Cross line. A few hours' stop was made at Halifax, which gave a little opportunity to see the interesting drift at that point. St. Johns was reached on June 25th without noteworthy event, unless it be that an iceberg south of Newfoundland, two at the entrance of St. Johns Harbor, and three or four on the distant horizon, gave a feeble prophecy of the ice conditions that were in store for us at the north. We remained at St. Johns awaiting the fitting out of the Falcon, a sealing steamer which had been chartered for the trip, until the 7th of July. The larger part of the interval was spent in the study of such geological formations as were accessible, especially glacial deposits. By the kindness of Dr. Taite I was able to see the interesting formations between St. Johns and Petty Harbor. Through the good offices of Mr. James P. Howley, government geologist, and the signal generosity of the Messrs. Reid, builders and operators of the Newfoundland Western & Northern Railway, Dr. Ohlin, Dr. Wetherell, and myself were permitted to spend four days in the interior, with all the facilities and comforts which a special train, under the personal direction of Superintendent Reid, could give, and with the added felicity of the lucid explanations of Mr. Howley, covering not only the region immediately traversed, but very much beyond. The road is in process of building for the government, and most of the

excavations are fresh and unmodified. Our trip extended about 250 miles into the interior. I hope to give some of the results in the JOURNAL during the year.

It is worthy of more than passing note that Mr. Howley, as government geologist, was entrusted with the location of the preliminary line for this road, and, though it bisects the island, passing through a wooded and almost wholly unsettled region, he was able to lay it down with such fullness of knowledge and good judgment that only slight departures were found advisable on fuller surveys. It is equally gratifying to make note of a government reposing the determination of the most important feature of its greatest commercial undertaking in the hands of its scientific adviser. The builders and operators of the road, the Messrs. Reid, appear equally appreciative of Mr. Howley's knowledge and counsel. The road is to terminate at the southwestern angle of the island, traversing the coal beds of the southwestern portion which Mr. Howley has recently exploited with favorable results. The completion of the road and the establishment of a steam ferry to Cape Breton will very greatly improve the now very poor communication between the mainland and St Johns, the point of departure, directly or indirectly, of so many Arctic expeditions.

On the 7th of July the Falcon, a stanch, full-timbered sealing steamer, specially fitted for ice work, and commanded and manned by experienced Arctic navigators, was ready, and the start was made.

Our course was direct to Cape Desolation, South Greenland. The voyage was almost without incident to that point, very little ice being seen. On the day after departure I noticed only two small masses of ice, on the day following, only one, and on the next two days, none at all. When this is compared with the much larger amount of ice reported off the coast of Labrador and Newfoundland by other vessels, and with the observations made on our return voyage, it seems to warrant the inference that the berg-bearing current was comparatively narrow, and that it hugged the mainland coast somewhat closely. If this is a

general fact, the total amount of ice drifting south is liable to be exaggerated in estimates based on the reports of coasting vessels. My observations farther north lend support to this; but of course the observations of a single voyage are much too slender to justify a conclusion.

Early on the morning of the 12th we sighted Cape Desolation, which lies about 150 miles west-northwest of Cape Farewell. The first glimpse of the topography of Greenland was full of suggestiveness. The aspect of its coastal mountains at once arrested attention on account of their marked ruggedness and angularity. The sky lines were strongly serrate, and the lower angles generally sharp and harsh, except, in some measure, near the base. Flowing contours did not much enter into the general view, though they might be found here and there by search. The dominant lines of sculpture lay in vertical, not in horizontal, planes. The inference was, therefore, close at hand that they owe their fashioning to the familiar meteoric agencies that work vertically, and not to the horizontal rasping of ice flowing out from the interior. This may not be wholly true of the lower contours which could not be seen to good advantage. Glimpses of the great inland ice cap were caught at intervals between the mountain peaks. According to the charts of Greenland, the border of the inland ice here lies but a few miles back from the coast line, and this nearness intensifies the significance of the unsubdued angularity of the coastal mountains. The bearing of this angular topography upon the problem of the former extension of the ice, and especially upon the broad question whether the ice sheet of Greenland once crossed the Baffin basin and became the source of the North American glaciation, as held by some geologists, at once presented itself, and stimulated as careful a scrutiny of the coastal topography as was practicable. This line of observation was continued assiduously throughout the whole length of coast followed, from Cape Desolation to Inglefield Gulf, as far as the circumstances of the voyage permitted, both going and coming. Fogs and night made many breaks in the series, but out of the something more than 1100 miles of coast

skirted, sufficient was seen to afford a fairly good basis for drawing a conclusion, so far as this kind of inspection would justify one at all. As I hope to discuss these observations collectively, they will not be further referred to in this sketch.

We had little more than come near enough for a clear view of the coast of Greenland before we encountered the outer edge of the East Greenland ice pack. It is an interesting fact that the well-known Arctic current which flows southward along the eastern coast of Greenland, bearing a formidable ice pack, curves around Cape Farewell and follows the western coast *northward* for several degrees of latitude, though it becomes broadened and scattered somewhat in this portion of its course. It then gradually recurves to the west and south and descends the Labrador coast, its burden of ice being progressively melted and dispersed. The charts name Holstensborg, which lies about seven degrees north of Cape Farewell, as the limit of this north-flowing current.

We found this stream of floe ice very compact and closely hugging the coast south of Cape Desolation. An estimate of its breadth by an officer of the vessel was fifteen or twenty miles, but a liberal allowance for probable error should doubtless be made. It is reported to be often much wider than this. At the point we encountered it the outer edge was quite sharply defined, and although the sea was unusually calm, the presence of the pack was announced at some distance by a continuous roar arising from the action of the ocean swell on the border of the crowded floes of ice. Outside of this compact stream, small masses of much eroded ice were scattered over a narrow belt, forming a slight bordering fringe. The ice of the main pack was quite firm and solid. To a large extent it retained its original tabular form, but not a few of the masses were reduced to very irregular and often very picturesque shapes. The melting to which all had been subjected was notably more rapid at the edge of the water than either above or below, and the result was a girdling incision at the water level tending to reduce the mass to a double tabular form, which was sometimes carried so far as to

approach the hour-glass form. The thinner, and usually smaller, table was naturally above, and the thicker and larger below, for the obvious reason that the greater mass of the ice was submerged. The breaking away of segments of these tables and various other inequalities of reduction often resulted in the tilting of the mass and the establishment of a new zone of maximum melting, leading on to further inequalities. While other agencies participated in forming the odd shapes assumed by the larger masses of ice, they appear to have been chiefly due to the superior rate of melting at the water's edge. It was only when the process of dissolution had reached an advanced stage that the more unique and fantastic forms were usually assumed. These were naturally most prevalent among the scattered masses on the border that were more freely bathed by the warmer surface water of the open sea.

The odd forms usually have, as a common feature, a submerged, massive base from which irregularly eroded portions stand forth. This base is the remnant of the lower table already mentioned, which retains much of its massiveness after the air and surface water and direct sunlight have wasted the upper part. To these massive bases the floes often owe their preservation long after their own slenderness and ill-balanced proportions would have wrought their destruction. Fragile columns, with or without entablatures, slender pinnacles, and delicate forms of various types, stand forth from these submerged bases, giving, at a little distance, an impression of such fragility as to lead one to wonder how they retained their integrity, until a near approach revealed the substantial base. A great variety of imitative forms are observable. Often the exserted portions resemble the limbs of an inverted animal. Not uncommonly the more massive projections from the submerged base stand forth like the prows and poops of oriental ships. Resemblances to mythological creatures, to architectural structures, to sea birds, to plants, and likenesses of all sorts might be imagined without much exercise of the fancy. These odd forms, however, were quite subordinate in size and number to the simpler thick pans merely worn more or

less about their edges. The aggregation of these made up the great mass of the ice pack.

The ice of the floes was often very thick, and, although no measurements were made, it seemed within safe limits to estimate the depth at fifteen to twenty feet and occasionally more. It retained so much of its integrity of structure as to give exquisitely beautiful tints of green and blue. The blue tones appeared to be chiefly due to light transmitted from the sky, the green to light that arose from beneath the water, thrown back by submerged, projecting shelves. The intergradation of tints was beautiful beyond expression.

A few, but only a very few, icebergs were embraced in the ice pack; from which the inference is drawn that either the East Greenland glaciers do not freely put forth icebergs, or that they still remained locked up in the icebound harbors of the coast. The same inference must be extended, I suppose, to the glaciers of the west side so far as skirted by this current. The process of developing fantastic forms among the icebergs was apparently identical, in large part, with that involved in the sculpturing of the ice floes.

But I have run ahead of my narrative somewhat. On encountering the border of the pack off Cape Desolation about nine o'clock on the morning of the 12th, the course of the vessel was turned westward and skirted its edge until midday, when the pack was found more scattered, and the Falcon entered it, worming her way from opening to opening, for the greater part, but forcing a passage by direct collision when necessary. The floes, however, continued to be measurably thickset, particularly toward the coast. A direct crossing of the stream seemed to grow more difficult as it was penetrated, and towards evening the course of the vessel was directed to the westward to escape the closer packed ice near the coast. Several hours were required to reach the more open portion, and during the night, and most of the following day, there were frequent encounters with belts of ice. These were usually separated by tracts of open water. The northern limit of the ice pack, as seen by us, lay nearly opposite

the Frederickshaab glacier, Lat. 62°30′. This gives an extent along the coast north of Cape Desolation of about three degrees.

The wrapping of the East Greenland ice pack about the southern extremity of the island greatly affects the climate of the coast, and doubtless the glaciation of the interior. The harbors of this part of the coast are reached only with difficulty during the early part of the summer; indeed, during June and July the coast between Lat. 60° and 65° is less accessible than that between Lat. 65° and 70°. We found East Greenland ice still in the inlets and among the islands about Goodhaab (Lat. 64°) on our return in the early part of September.

As previously remarked, comparatively few icebergs were seen among the floes from East Greenland. Soon after our escape from the pack, a feeble train was observed nearly opposite the Frederickshaab glacier. Only a dozen rather small icebergs composed the procession. Beyond these, few icebergs were seen until, two days later, we encountered a grand procession streaming out from Disco Bay.

While we were immediately opposite the Frederickshaab glacier, the coast was shrouded in low clouds and fog. But these cleared away before we were out of the range of vision, and, through the aid of field glasses, we had a measurably satisfactory, though distant, view of this most beautiful glacier. Our position was such as to make its magnificent profile, as it issued from among the peaks of the coastal mountains and stretched, with a gentle decline, far out on the lowlands that form the immediate shore, the most striking element presented. Notwithstanding its great massiveness, its freedom from constriction, and its relatively gentle decline, it was strongly crevassed at some points on its flanks, and on its crest line. On its lateral border vertical ice-walls appeared, but from our position I could not detect any at the extremity.

On the evening of July 15th, we encountered a grand procession of icebergs moving southwesterly from Disco Bay, into which they had been discharged (with perhaps few exceptions) by the Jacobshaven glacier. Thirty were in sight at once. It

was not so much the number, nor the size, as the variety and picturesque beauty, that commanded admiration. The Jacobshaven icebergs are noted for their pinnacled and angulated forms. It is even held by Greenlanders that they may be distinguished from the bergs of other glaciers by their distinctive forms. From what I saw, I should think this measurably true.

Early on July 16th, we arrived at Godhaven, on the south side of Disco Island, and, after the customary formalities of entrance to a Greenland port, visited the lower glacier in Blase Dale,

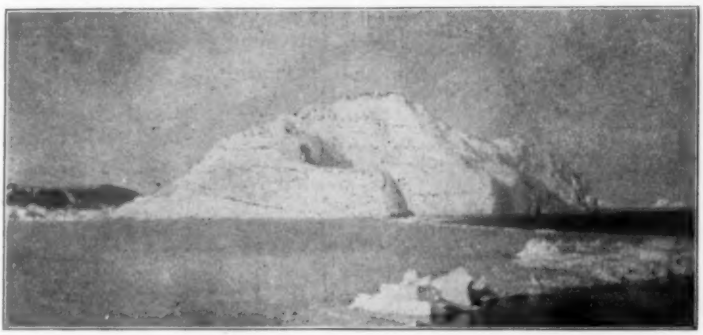

FIG. 1. Iceberg off the Crimson Cliffs, northern part of Baffin's Bay. Characteristic floe-ice of the region in the foreground.

which creeps down from a local ice cap covering the southwestern uplands of the island. This glacier was again visited on our return, forty-eight days later, and this constitutes the longest interval afforded me for the study of seasonal effects on the surface of the same glacier. Disco Bay was found thickly dotted with Jacobshaven icebergs, and presented a most enchanting picture, set off, as the picturesque ice masses were, by a calm, blue sky, a clear, genial atmosphere, and the red-brown cliffs of Disco Island. While at Godhaven we were fortunate enough to secure specimens of the famous "Ovifak" iron.

Leaving Godhaven on the evening of July 17th, we skirted the west coast of the island, and on the afternoon of the 18th

encountered a magnificent procession of icebergs emanating from the Umanak Fjord. These were much larger, but more tabular and less picturesque, than those derived from the Jacobshaven glacier. Thirty or forty of the larger order were in view at the same time, besides many smaller ones. They probably came from the great Karaiak glacier. Their drift was southwestward. A more scattered procession moved parallel to this on the north. It appeared to come from the straits between Ubekyendt Island and the Svarten Huk Peninsula, and was doubtless chiefly derived from the Kangerdluksuak glacier.

During the night of the 18th the first northern pack ice was encountered at a point south of Upernavik, between latitudes 72° and 72° 30′. This ice was much thinner and more completely tabular than that of the East Greenland pack previously described. It lay lower in the water, and was usually confined, even in its most solid portions, to a thickness of from three to five feet. Except where broken up at the edges by the collision of the pans, it presented little relief from the water's surface. The general expression throughout the whole of the northern portion of Baffin's Bay, so far as seen by us, was not unlike that of ordinary river or lake ice when broken up, save in its greater expanse. In this respect it contrasted somewhat markedly with the East Greenland ice, which, by reason of the tilting of the thick masses, due to irregular melting, presented a quite unequal surface. These differences, which spring from original differences in the thickness of the parent ice sheets, doubtless point to different conditions of origin and history. The floe ice of the upper part of Baffin's Bay is chiefly the product of a single season, that of East Greenland may be inferred to be the product of several seasons' cumulative work, or else to come from a region of much more intense cold, and more prolonged season of low temperature; the former more likely than the latter.

On the 19th much ice was met, which to the experienced officers of the ship clearly foretold the unusual amount of ice which we subsequently met to the northward. A most charming view of the "midnight sun" was presented that night, as the

vessel zigzagged its way through the ice floes that filled the whole horizon and gave a strange, wintry aspect to the whole scene.

The hope of the captain was that, turning away from the coast near Upernavik, he might be able to effect the "middle passage" across Melville Bay, direct to Cape York, but early on the morning of the 20th, after about a day's struggle with the ice, the attempt was abandoned, and the Falcon turned back toward the coast. All day she worked about through the leads, or bunted

FIG. 2. Icebergs of Cape York; still held in the bay ice that remains attached to the shore. The point of view is about two miles off Cape York, which lies a little to the left of the picture. Cape York Eskimos in the foreground.

her way from one to another, in the endeavor to reach the more persistent lanes of water that are usually developed between the moving ice of the bay and the stationary ice that still remains attached to the shore. Success in this was reached during the evening, and the sail of the 21st was a continuous delight, as the vessel followed a broad lane concentric with the coast of Melville Bay, affording a rare opportunity of studying with our glasses the undulating slope of the inland ice that forms the horizon throughout almost the entire circuit of the bay. From the extensive ice walls at its margin numerous large icebergs had

broken away, but were still detained in the fixed bay ice. A series of promontories and nunataks break the continuity of the ice border. The most remarkable of mirages occupied large segments of the horizon nearly all day, and limited the field of good observation, but their extraordinary character (there being two, three, and even four reflecting horizons superposed on each other, giving rise to imitations of castellated structures of the most fantastic and beautiful forms) was some compensation for the illusions they constantly threw over large portions of the landscape.

That afternoon, when within sight of Cape York, and in the highest spirits over the delightful passage of so much of the dreaded Melville Bay, the lane we had followed to so great advantage led away from the land, and became broken and intricate. During the night the ice closed upon the vessel while trying to force her way through a narrow passage, and she was nipped astern and her rudder severely strained, but not permanently injured. The vessel was held fast, with a strong "list," all the following day, which was Sunday, and so, by no virtue of ours, the day became "a day of rest" and, I need scarcely add, of more than puritanical sobriety. About three o'clock next morning, however, the ice relaxed, the vessel settled back to her normal position, and again began threading and ramming her way through the pack with such success that by ten o'clock she was in a wide lane leading to Cape York, which was reached at noon; or, to speak more accurately, the fixed ice, which extended about two miles out from the cape, was reached. During a short stop here specimens of the rock in place (gneiss) and of the drift (gneisses, granites, syenites, red and white quartzites, etc.) were collected, photographs of the glaciers and the icebergs were taken, and a few general observations made. The bay east of the cape was full of icebergs derived from the glaciers that debouch into it, and at its mouth there was a very notable cluster, probably aground. Numerous large icebergs also lay along the coast northwest of Cape York, skirting the "Crimson Cliffs" as far as Conical Rock. As we sailed along these Crimson Cliffs (their color is due in part to

"red snow," *protococcus nivalis*, and in part to red lichens, and not to the hue of the rock) I noted eleven glaciers, or glacial lobes, coming down from ice caps whose heights did not exceed three thousand feet. A few miles beyond lies the Petowik glacier, about seven miles wide. It descends by a gentle inclination from the inland ice, its course being unusually direct, and its surface smooth and unruptured by crevasses. In general

FIG. 3. *Contrasted Topographies.* No. 1.— Dalrymple Rock, near the Greenland coast at the mouth of Wolstenholme Sound, about 77° N. Lat. Formed of hornblendic gneiss. Illustration of angular outlines.

habits and relations, it resembles the great Frederickshaab glacier, but it is smoother, less massive, and much less impressive.

On the morning of the 24th we were off the mouth of Wolstenholme Sound. A landing was made at Dalrymple Island, one of the notable nesting haunts of the eider duck. While the hunters of our party made a generous addition to our provisions, I secured an excellent set of specimens from the finely foliated series of hornblendic gneisses that form the island. Saunders Island, which lies not far to the north, was an interesting object,

as it is composed of conspicuously stratified red rock (with little doubt sandstone) banded with gray layers. As almost the whole of the coast to the southward is composed of crystalline rock, the introduction of the clastic series here commands an interest it would not otherwise possess. Wolstenholme Island, to the southeast, presents the same appearance as the "Crimson Cliffs," which are gneissic. Distant views of the glaciers in and

FIG. 4. *Contrasted Topographies.* No. 2.—Southeastern Carey Island. Situated in the midst of the northern part of Baffin's Bay, thirty or forty miles from the Greenland coast, W., N. W. from Dalrymple Rock, and formed of almost identical rock. Illustration of rounded outlines.

north of Wolstenholme Sound, and of the ice cap covering the adjacent plateaus, were afforded.

One of the missions of the expedition was to search for further information respecting the missing Swedish naturalists, Björling and Kallistenius, who were wrecked on the southeasternmost of the Carey Islands, two years ago. The course of the Falcon was therefore turned westward toward them. A landing was effected during the afternoon, and the search continued until midnight, with no better results than the mournful satisfac-

tion of finding many relics of the unfortunate party, and of collecting, and re-interring with burial service, the bones of one of the party, which had been disinterred from their shallow grave and scattered about, apparently by burgomaster gulls. Collections of rocks were made from the islands, which are gneissic. Foreign drift was found on them, the significance of which is quite important taken in connection with other data gathered with reference to the former extension of the ice. This will be discussed later.

Early on the morning of July 25th, the date named for reaching Inglefield Gulf by Mr. Bryant in his prospectus, the Falcon entered Whale Sound, the southern entrance to the gulf. Finding the inner portion of the sound covered with unbroken ice, the vessel passed between the Northumberland and Herbert Islands into Murchison Sound, the northern entrance to the gulf. This was also found covered with ice, and after searching in vain for a practicable way through it, the Falcon was made fast to the ice, only some forty odd miles from her primary destination, which she would have reached on schedule time but for the unusual tardiness of the breaking up of the ice. The persistence of the ice here, and along the coast of Ellesmere Land, and in Jones Sound on the west side of Baffin's Bay, rendered the geographical work contemplated by Mr. Bryant almost fruitless. It very considerably modified my own work, and caused some loss of time, but was not without its very considerable compensations, so far as my part of the work was concerned. By reason of their detention I became much indebted to the other members of the party, and particularly to Professor Libbey, for hearty and very considerable aid. Thwarted in their own immediate plans, they turned cordially to the other scientific work which was available; and it is well-nigh impossible to be detained at any point on the coast north of Cape York where glaciers and ice caps profitable for study are not near at hand. To Professor Libbey's rare skill in photography science will be indebted for many choice views of glaciers which the kodak, my own rather uncertain dependence, might not have furnished, though this

proved better than I had reason to expect, and out of the 350 views taken I shall find ample illustrative material.

On the day following our arrival a base line was measured on the ice under the superintendence of Professor Libbey, and with the assistance of Mr. Bridgman and Dr. Wetherell, with a view to the more accurate mapping of the surrounding region. This was abandoned the next day, however, for the ice having relaxed and a lane having opened northward, the Falcon moved to a point close in to the north shore, opposite the Igloodahomyne glacier,

FIG. 5. The Igloodahomyne Glacier, near mouth of Murchison Sound, North Greenland. A dependency of the inland ice.

in the hope of finding broken ice and a practicable passage along the north shore. The Igloodahomyne glacier was examined by Professor Libbey, Dr. Wetherell, and myself on the following day. During the next two days the vessel was advanced several miles into Inglefield Gulf, where it was again arrested opposite the glaciers of the Red Cliff peninsula, which furnished a profitable field of study until August 4th. Meanwhile, communication had been opened over the gulf ice with Lieutenant Peary's headquarters, and we learned with extreme regret that the extraordinary severity of the spring storms on the ice cap had so nearly destroyed his dog team, and had so far crippled his men, as to compel a return to headquarters and a postponement of his exploration of the extreme borders of Greenland until next year.

On August 4th, by invitation of Lieutenant Peary, I accompanied him to his headquarters, Anniversary Lodge, on Bowdoin Bay, (Lat. 77° 44′), and made that a working centre until August 23rd. Here, with the great ice cap near at hand, the local ice cap of the Red Cliff peninsula directly opposite, and nine glaciers of varying forms and habits within a half dozen miles, I enjoyed every facility which the phenomenal situation and the great kindness of Lieutenant Peary and his party could furnish. In no small degree the misfortune that turned them back was my gain. Lieutenant Peary's intimate knowledge of the region, his wide observation upon the glaciers of middle and northern Greenland, his counsel and his personal guidance, and his ample equipment for northern work, all of which were freely placed at my service, were of incalculable aid to me. Mr. E. B. Baldwin, meteorologist to the party and an enthusiast in exploration, was my nearly constant guide and companion, and did all in his power to aid in the work. One would be indifferent indeed, if, under these circumstances, he did not press the work to the utmost limits of physical and mental endurance, for the continuous daylight put no limit to daily hours.

I learned with gratification that Lieutenant Peary had undertaken the mapping of the geographic features of a large territory adjacent to Inglefield Gulf, and that he had commenced systematic observations on certain of the glacial phenomena, among others the measurement of the rate of glacial motion by stakes and transit, and by a series of photographs. This proved peculiarly fortunate, under the circumstances, for, though I went with a full instrumental outfit for measuring glacial movement, and for making such geographic determinations as might be necessary for plotting the glaciers studied, the adversities of the season that made it necessary to leave the Falcon thirty miles from the main field of work, and to make the journey by foot or by sledge over uncertain bay ice, much broken by leads, rendered the transportation of the outfit impracticable. The geographic outlines which I shall be permitted to use in these articles are chiefly the contribution of Lieutenant Peary. The

fuller data which he will himself publish in due time, relative to glacial distribution, movement, and many other features, will be an important accession to glaciology.

A detailed narrative of the excursions made from Anniversary Lodge to the ice caps and to the adjacent glaciers does not seem to me to possess sufficient interest, apart from the results, which will be fully described, to warrant giving it a place here.

Between the 23rd and the 26th of August, the Falcon, which had previously reached the Lodge, visited several points at the head of Ingefield Gulf, and an opportunity was afforded to see, at hand, two of its great glaciers, the Leidy and the Hubbard, and to view from near points a complete panorama of the remarkable group that gathers about the head of the gulf. These lie about one hundred miles back from the general line of the west coast and are opposite the greatest breadth of Greenland's ice cap.

On the 26th of August the return trip was begun, and, besides further studies of coastal topography, a visit to two additional glaciers on Disco Island, and some study of a coastal plain, very analogous to that of Norway recently described in the JOURNAL by Dr. Reusch, the journey possessed little of scientific interest. Floe ice was still abundant along the "Crimson Cliffs" and the coast east of Cape York, but the northern part of Baffin's Bay was free from floes on the line of our pasage, and almost free from icebergs. On the coast of Labradors, which we somewhat closely approached, only a few icebergs were seen. We arrived at St. Johns, Newfoundland, on September 15th, which may be said to be schedule time. Here I parted with my aid, Mr. Z. Butler, who had rendered faithful service throughout the trip. Leaving the Falcon at St. Johns in company with Mr. Bridgman, with whom I parted at Halifax, I returned by way of Canada, stopping two days to see the interglacial formations at Toronto, which promise such important evidence bearing on the diversity of the glacial period.

T. C. CHAMBERLIN.

ON A BASIC ROCK DERIVED FROM GRANITE.

WHILE studying the hematite deposits of St. Lawrence and Jefferson counties, New York, under the direction of Dr. James Hall, State Geologist, the writer had occasion to examine some interesting rocks associated with the ores, which are worthy of note.

A brief description of the rocks is given in the report on the region presented to Dr. Hall, in which especial attention is paid to their relation to the problem of the origin of the iron ores. The aim of the present paper is to supplement that report with a more complete account of one phase of these rocks, occurring at the Old Sterling mine, in Antwerp, Jefferson county.

Mode of occurrence of the rock.—The mine consists of a large open pit, together with considerable underground workings. The surface rock is Potsdam sandstone, beneath which the ore, a red hematite, occurs in large irregular masses, intimately associated with a rock of entirely different character, which is the subject of this paper. The contact between this rock and the ore is extremely irregular, as is well shown in the open pit where the ore has been removed leaving the rock in projecting knobs, ridges, and walls, with intervening pockets and hollows. In the underground workings it is not uncommon for the ore to be suddenly cut off by the rock and to appear again after passing through a greater or less thickness of it. The contact is evidently irruptive and is precisely like the contacts of granite and limestone which are common in the region, although the rocks involved have a very different appearance. Emmons,[1] who has given the only detailed account of the ore and associated rock, considered them both igneous, and called the rock serpentine, a name which has clung to it ever since. The facts adduced by Emmons

[1] Geology of New York. Second District, p. 97.

to prove the igneous nature of the rocks were hardly of a char acter to justify the conclusion, and that he was right in regard to the so-called serpentine must be regarded as a mere matter of chance.

Description of the rock.—A hasty examination of many specimens of the rock would seem to warrant Emmons' determination of it as serpentine. It is dark green or black, massive, and very fine grained or quite aphanitic, with rather waxy lustre, and abundantly slickensided. Thus far it is precisely like serpentine, and many specimens show no other prominent features. But most of the rock is mottled with abundant white, vitreous spots, of extremely variable size. Where these are large enough to be clearly seen (and they may reach three or four inches in diameter), it is evident that they are fragments of quartz. Specimens in which the grains are small and evenly distributed closely resemble a porphyritic rock with glassy or aphanitic groundmass. In the presence of this quartz, there is a marked divergence from the ordinary character of serpentine.

The slickensides which are so abundant in hand specimens are developed on a large scale in the rock exposed in the mine pit. They run in every direction, and on this account most of the exposed surfaces are slickensided, being, as a rule, curved and showing a beautiful polish. Such surfaces measuring more than one hundred square feet are not uncommon. A good example appears in the centre of the pit upon a dome-like mass of rock.

Origin of the rock.—Accepting the evidence afforded by the contact, that the rock must be igneous, a difficulty is met at once in its apparently contradictory features. Its serpentinous aspect suggests derivation from a basic rock, but conflicting with such a supposition is the presence of much quartz. This mineral is, moreover, so distributed that it cannot be accounted for as inclusions, or, to any great extent, as secondary. These facts, noted in the field, led the writer to a close examination of the exposures in the hope of finding some portion of the rock which, through less complete alteration, would give some clue to

its origin. The examination resulted in the finding of several small patches, which, though considerably altered, still retain enough of their original character to show conclusively that they are granite. The transition between the fairly fresh granite and the serpentine-like rock is very gradual, the feldspar losing its fresh appearance and passing over into a green aggregate, while the quartz decreases in quantity, till in some specimens it is wholly lacking. To the naked eye no other minerals are visible, the original granite having been a coarse, pegmatitic variety.

The alteration of an acid granite into a nearly black, apparently basic, rock is an exceptional phenomenon, and yet in this instance the field evidence alone is of such conclusive nature that there can be no doubt that such is the case. Furthermore, the operation has taken place on a large scale, for there are hundreds of tons of the altered rock in sight, and it is impossible to tell how much is underground.

Additional evidence that the rock is an alteration of granite is afforded by the fact that at the bottom of the underground workings the ore rests upon a granite which differs only in freshness from the material of the least altered patches in the serpentine. But even this granite shows the beginnings of the alteration.

Megascopical aspect of the alteration.—A specimen of granite from the bottom of the shaft is a decidedly coarse-grained rock, made up of quartz and feldspar, the latter predominating. Besides these distinct minerals there is a limited amount of greenish material which fills the interstices between the essential minerals. The latter have very irregular outlines, the feldspar occurring in decidedly larger individuals than the quartz. The former mineral generally has bright cleavage faces; less often they are dull and earthy. The color is gray with a very faint pink tinge. The quartz is colorless and clear, with the usual vitreous lustre.

The granite of the least altered patches in the "serpentine" differs from such a specimen in having a larger amount of the

green aggregate, and in the color of the feldspar. This color is a decided pink or red, but there can be no doubt that it is itself a result of alteration, having replaced an original gray like that of the feldspar of the specimens from greater depth. These patches of comparatively little altered granite are only a few feet in diameter, and shade off into the typical serpentine-like rock on all sides. The passage is gradual as a whole, but more rapid in some spots than in others, so that, while it is impossible to draw any line of demarcation in the stages of the process, lines uniting equally altered portions around a granite core would be extremely irregular.

From the centre of such a core outward the green aggregate increases, while the feldspar gradually disappears, till finally there remains a waxy, deep green mass holding fragments of quartz. In some highly altered specimens the quartz is very conspicuous against the dark groundmass; in others it is entirely absent, though this is never true of large masses. In still other cases lumps of quartz several inches in diameter occur. These always lie close to one another and usually along definite zones, showing clearly that they are fragments of crushed veins.

In the slightly altered granite cores there are no conspicuous indications of disturbances, the slickensides being confined to the highly altered phases of the rock, in which, as stated above, they are very prominent. This fact, together with the great irregularity in the direction of the slickensides, suggests that the movements which have formed the polished surfaces may have resulted from changes of bulk in the rock attendant upon the alteration, as in the case of true serpentines.[1]

It should be noted, however, that the granite cores are so small that they might fail to give evidence of considerable movements in the mass as a whole, and such movements may account for the slickensides, as they do for the crushing of the quartz in veins and scattered through the rock. That the latter

[1] J. S. DILLER, Geology of the Lassen Peak District, 8th Ann. Rept., U. S. G. S., p. 401.

is the case is clearly shown by the microscopic structure of the rock, as stated below.

Microscopical details of the alteration.—A microscopical examination of sections illustrating all of the phases of alteration shows some variation in the intermediate stages of the process, but considerable uniformity in the final results.

Sections of the least altered granite show it to consist of orthoclase, microcline, and quartz, with occasional stout prisms of apatite and irregular masses of tourmaline. Granite of this character is quite common in the region, and has been previously described by the writer.[1] The feldspar has the common dull and cloudy appearance. The quartz contains abundant fluid inclusions and great numbers of the hair-like bodies usually considered rutile. Undulatory extinction is constant, and much granulation is shown in nearly all sections.

Alteration begins with the development of a greenish aggregate in the feldspar. This may form irregular masses, or may be confined to cracks. Very often quite large portions of the aggregate have angular outlines formed by cleavage cracks of the feldspar. Where the aggregate has formed in a zone of crushing, it usually contains small, angular fragments of feldspar which at first sight look like crystals of some newly formed mineral. The areas of the aggregate are very unequally distributed in the granite, one portion of a specimen being greatly changed, while another portion remains unaltered. In some cases this is clearly due to the arrangement of cracks and crushed zones, but often there is no apparent reason for it. As the alteration proceeds the areas of the aggregate gradually extend until they entirely replace the feldspar, leaving no trace of its former presence.

At the same time the quartz is attacked, but, as a rule, it yields much more slowly than the feldspar. In the absence of cleavage the alteration proceeds along the borders of the grains and in the irregular cracks. The areas of alteration product

[1] C. H. SMYTH, JR.: Petrography of the Gneisses of the Town of Gouverneur, N. Y. Trans. N. Y. Acad. Sci., XII., p. 210.

thus formed never have the sharp, angular outline that they have in the case of the feldspar. Irregular tongues of the aggregate eat their way into the quartz, gradually spreading, cutting across, and separating grains originally continuous, and finally entirely replacing them. Such complete replacement of the quartz is, however, exceptional, and seldom extends through any considerable mass of the rock. Although the quartz usually lags behind the feldspar in the process of alteration, the degree of change in the two minerals has no constant relation. For, on the one hand, a section whose feldspar is completely replaced by the aggregate may retain most of its original quartz, while, on the other hand, a section with quite fresh feldspar may show much alteration in the quartz. Not uncommonly the alteration proceeds most rapidly along the contact between the quartz and feldspar. It is hardly probable that this results from chemical causes; it must, rather, be due to the more ready circulation of solutions along these contacts. This may, perhaps, be accounted for by a tendency for quartz and feldspar to separate under mechanical strains.

The extreme result of the alteration is a mass of the greenish aggregate with no trace of either quartz or feldspar. But more commonly the rock consists of the green aggregate with a greater or less number of quartz grains.

Under low powers the aggregate has a felt-like appearance, and a green or yellowish color. With crossed nicols it shows aggregate polarization of varying intensity, the most thoroughly altered sections being nearly isotropic.

With higher powers the aggregate is seen to be made up of small, irregular scales, with a single pronounced cleavage. These scales are quite pleochroic in green and yellow, have a parallel extinction, and low double refraction. From these facts it is very probable that the scales consist of some member of the chlorite group, or of one of the nearly related hydrous silicates. An absolute determination of species is out of the question, and it is, moreover, probable that more than one species enter into the composition of the aggregate. Some sections show mingled

with, or replacing, the green scales, colorless scales with similar cleavage, but no pleochroism, and having strong double refraction. In this case the mineral is probably muscovite. It is much less abundant than the chloritic mineral and disappears as the alteration becomes more complete. By this it is not meant to imply that the muscovite is an essential step in the process of change, as in most cases there is no trace of it, even in the earlier stages of alteration. Other substances are present in minor quantity, and generally of undeterminable character. In many cases they are evidently the result of the alteration of the normal green aggregate by ordinary surface agents, with the production of iron oxide, carbonates, etc. Such weathering often brings out very clearly a wavelike banding in the sections, which very closely resembles flow structure. When this structure appears in a section of the most highly altered rock, composed of the very low, doubly refracting aggregate, the likeness to a section of a glassy volcanic rock is striking.

Cataclastic structure is very pronounced in most sections, when the alteration has not proceeded so far as to hide it, and there can be no doubt that the crushing played an important part in the process of change.

Chemistry of the process.—As microscopical study gives no definite information in regard to the chemical composition of the altered granite, an analysis has been made of a carefully selected sample. For this purpose a specimen was chosen representing the extreme result of the process of alteration, being nearly free from quartz, with a deep green color and waxy lustre. A thin section cut from the specimen shows a mingling of green and yellow aggregates, with no trace of feldspar or quartz. The results of the analysis are shown in column I. No analysis has been made of the fresher granite, because even the best specimens are so much altered that the results obtained would give no clearer idea of the original composition of the rock than can be gathered from a consideration of its mineralogical composition.

	I.	II.	III.	IV.
SiO_2	29.70	26.88	29.45	46.90
Al_2O_3	17.03	17.52	18.25	35.73
Fe_2O_3	—[1]	—	8.17	—[1]
FeO	27.15	29.76	15.12	2.48
MgO	10.66	13.84	15.32	0.83
CaO	1.68	—	0.45	0.45
Na_2O	0.56	—	—	0.48
K_2O	0.10	—	—	6.41
H_2O	11.79	11.33	12.57	5.00
	98.63	99.33	99.33	98.88

I. Greatly altered granite, Old Sterling mine.

II. Prochlorite, St. Christophe.[2]

III. Delessite, Zwickau.[3]

IV. Alteration product of doubtful origin (probably derived from granite), Caledonia mine.

It has been shown that the original rock was an acid granite, consisting almost wholly of orthoclase, microcline and quartz, with no ferromagnesian constituents. From this there can be no doubt that it contained not less than 70 per cent. of silica, with a large content of alumina and alkalies, and little iron, magnesia, and lime. The analysis shows that the process of alteration consisted of a decided decrease in the percentage of silica and alkalies, with an equally marked increase of iron and magnesia, and the addition of much water. Moreover, this has not been a mere removal of some constituents, leaving relatively increased proportions of the others, but, on the contrary, there has been an actual addition of material from a foreign source. It is hardly necessary to say that the composition of this alteration product is totally unlike that of the product that would result from the alteration of such a granite under ordinary conditions. Of course the analysis represents, as already stated, the extreme result of alteration, but it is not probable that the results would

[1] The iron in I. and IV. is all calculated as ferrous, but there can be no doubt that some of it is in the ferric condition.

[2] Dana's System of Mineralogy, p. 654.

[3] *Ibid.*, p. 660.

be very different for an average sample. The silica would be increased by the grains of quartz, but would hardly exceed 40 to 50 per cent.

The results of the analysis and of the microscopical study bring into question the propriety of applying to the rock the name serpentine. Modern usage seems to justify the use of the designation "serpentine" for rocks composed largely of the mineral serpentine. But the analysis of the green aggregate composing the larger part of the rock under discussion shows a composition so different from that of serpentine, that there can be no doubt of the impropriety of applying this name to the rock. Analyses of different portions of the green aggregate would probably yield decidedly different results, so that it seems useless to attempt to identify it as a whole with any mineral species; but the analysis given, as well as the optical properties, indicates a much closer relationship with the chlorites than with serpentine. This relationship is illustrated by analysis II. and III., which are very similar to I., the difference being no greater than would naturally result from the variability in the composition of the minerals concerned.

Cause of the alteration.—In endeavoring to ascertain the cause which has led to such a complete change in the granite, it is evident that search must be made among the class of processes to which Roth[1] gives the name of "complicated weathering." For the alteration is not of a kind that could be produced by the simple agents of the normal weathering of rocks, nor do the facts indicate that it is a result of ordinary dynamic metamorphism, though, as stated above, crushing of the rock has been an important factor. The granite must have been attacked by some powerful chemical agent, whose action was not general, but, on the contrary, limited to this particular locality, and to such others as show analogous alteration products. A clue to the nature of the agent is afforded by the composition of the alteration product, and by the character of the associated rocks. From the analysis it is clear that the alteration has been brought about

[1] J. ROTH, Allgemeine und Chemische Geologie, Vol. I., p. 2.

by the removal of certain constituents of the granite, and the addition of a great amount of iron, with less magnesia and much water. The association of the altered granite with iron ore, suggests that the latter is in some way connected with the process of alteration. That such a connection does exist is shown by the fact that rocks similar to the altered granite, and sometimes of like origin, occur at all of the ore mines of this vicinity; while, on the other hand, nothing of the kind is found away from the ore, although granite is a very common rock.

Accepting the connection between the alteration of the granite and the presence of the iron ores, two hypotheses are suggested to account for the phenomena. The discussion of these two hypotheses involves the whole question of the origin of the iron ores, which is considered at some length in the report to which reference has been made. For present purposes only a very brief summary of the most salient points is necessary.

According to one hypothesis the granite is younger than, and has been intruded into, the iron ore. As a result of this intrusion the granite has undergone marked endomorphic changes, during, and subsequent to, the intrusion, becoming heavily charged with iron and assuming its present form. But this hypothesis is rendered doubtful (aside from its inherent weakness) by the absence of any contact phenomena in the iron ore, and by the presence of an analogous serpentine-like rock at another ore mine, which is derived from a finely laminated gneiss, instead of a granite. In fact, there is nothing to indicate that the change in the granite associated with iron ore is, in any way, the result of the action of heated solutions generated at the time of intrusion, while much evidence is at hand to prove that this is not the case. There is more probability in a modification of this hypothesis, by which it is assumed that the ore was originally siderite and that oxidizing meteoric waters changed it to the peroxide, with the production of much carbon dioxide, which, being carried in the percolating waters, might be a sufficiently powerful agent to bring about the alteration of the granite. This

explanation would account for the alteration of gneiss as well as of granite, but does not remove the difficulty afforded by the lack of metamorphism in the iron ore at the Sterling mine. There are, moreover, other facts which need not be discussed here, indicating that the ore is probably a secondary concentration younger than the granite. Upon this supposition is based the second, and, in the writer's opinion, more probable hypothesis to account for the alteration of the granite.

This hypothesis assumes that at the time of the granitic intrusion the ore had not been formed, its present place being occupied by other rocks, chiefly limestone. The ore was formed by the gradual replacement of the limestone, through the agency of solutions which at the same time produced the alteration of the granite. This explanation requires that a source shall be found for the solutions supposed to bring about the whole series of changes. It is believed that such a source exists in a ridge of gneiss which rises a few rods west of the mine. The rock of this ridge is highly pyritiferous and contains also much magnetite. As the result of weathering, the surface becomes rusty, and the pyrite almost wholly disappears, leaving the rock light and porous. While this pyritiferous rock is not shown directly at the mine, there can be no doubt of its presence, as its strike is such as to carry it very close to the ore body.

The oxidation of the pyrite yields solutions containing iron sulphates and sulphuric acid. These solutions must be capable of producing very marked chemical effects, and are just the sort of agent required to account for all the phenomena under consideration. Working down the dip and coming in contact with limestone and granite, they would change the former to an iron ore, with the consequent formation of solutions of lime and magnesia sulphates. These solutions, as well as those derived directly from the pyrite, would attack the granite, and, being very different from the common agents of alteration, the product of their action would naturally be of an unusual character, as is the case with the rock under consideration. The solutions would have much more powerful chemical action than the ordinary agents of

weathering and would supply the elements which, as analysis shows, have been added to the rocks.

While it is impossible to trace this process with precision, and there is no positive proof that it is what has actually occurred, still the explanation has much to commend it. It accounts for the association of the altered granite with the ore, and its absence elsewhere in the region, by assigning the alteration of the granite and the formation of the ore to a common cause. It explains the very unusual character of the alteration as the result of an unusual agent. Evidence of a general nature bearing in the same direction is afforded by the fact, stated by Roth,[1] that several of the hydrated silicates of iron and magnesia, to which the green aggregate of the altered granite is quite similar, are formed where the products of the weathering of pyrite act upon silicates. These facts seem sufficient to warrant the tentative acceptance of the hypothesis as a reasonable explanation of the phenomena observed.

Similar rocks elsewhere in the region.— As previously stated, the ore at all the mines of the region is associated with rocks more or less similar to that at the Old Sterling, and generally called serpentine. That these rocks have been subjected to a process of alteration analogous to that of the granite has already been suggested as probable, but it has not been found possible always to determine their original character. At the Dixon mine the "serpentine" is plainly an altered granite, like that of the Old Sterling. The "serpentine" at the Clark and Pike mines is an altered gneiss, but at the Caledonia mines its nature is somewhat uncertain. Here it is an aphanitic mass, showing, as a rule, no trace of its original minerals or structure. By Shepard[2] it was included in his mineral species Dysyntribite, whose variable nature was afterwards shown by Smith and Brush.[3] Its relation to the ore is such as to suggest an intrusion, but the

[1] J. ROTH, Allgemeine und Chemische Geologie, Vol. I., p. 238.

[2] R. U. SHEPARD, Am. Jour. Sci. (2) XII., p. 209. Treatise on Mineralogy, p. 146.

[3] J. L. SMITH and G. J. BRUSH, Am. Jour. Sci. (2) XVI., p. 50.

data are scanty and unreliable. The composition of the rock, shown in IV., is so different from that of the Old Sterling rock, as to raise some doubt of a unity of origin. This is particularly true when it is considered that the Caledonia rock, if derived from a granite, has generally lost all trace of its quartz, and yet has suffered less chemical change than has the Old Sterling rock, in which much quartz still remains. This fact might, however, be accounted for by some difference in the solutions causing the alteration, or by a more complete crushing of the granite. The latter explanation is particularly probable, as the granite of the region not uncommonly runs over into very fine granulitic phases. There are, moreover, very pronounced indications of crushing and shearing in the rock of this locality. Some specimens of the rock, however, contain quartz, and in thin sections closely resemble the Old Sterling specimens. Examination of these sections makes it difficult to avoid the conclusion that the Caledonia "serpentine" is also an altered granite. The microscopical evidence in favor of such a conclusion is very strong, though not affording, as in the case of the Sterling rock, a complete demonstration.

From the facts at hand it may be stated that the so-called serpentine of the various mines is derived from different rocks, whose character must be determined in each case. There is nothing to indicate that the original rock was, in any instance, a basic intrusion, but, on the contrary, where it has been found, it is decidedly acid. Moreover, the alteration products are not sufficiently uniform in character to be grouped under a specific name, and, even were this done, the term serpentine, which has always been applied to them, would have to be supplanted by something more in accord with their composition.

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THE QUARTZITE TONGUE AT REPUBLIC, MICHIGAN.

I.

On Major Brooks' geological and topographical map of Republic Mountain and vicinity, Plate VI. of the Atlas of the Geological Survey of Michigan, 1873, a tongue of the upper quartzite (his formation, XIV.) is correctly represented as forking from the main mass of the same rock, and running northwest along the top of the Republic bluff, a thin wedge of the underlying specular jasper (his formation, XIII.) being interposed between them.

No explanation of this singular occurrence was given by Brooks in the text of the Michigan report.

Dr. M. E. Wadsworth[1] in 1880, as the result of personal examination, concluded that the supposed quartzite tongue was really a granite dike, intruding the jasper.

In consequence of later studies[2] by himself and his assistants, Dr. Wadsworth has recently decided that his former determination of the tongue as a dike of granite was erroneous, and that it is in fact quartzite. In this latest publication he endeavors to explain the peculiar relations by the assumption that the interposed wedge of specular jasper does not belong to the lower series, but to the upper, and was deposited later than the quartzite tongue.

In the autumn of 1891, in the course of extended work on the surface and underground at Republic, I studied this question in some detail, and concluded that the phenomena were due entirely to faulting.

[1] Notes on the Geology of the Iron and Copper Districts of Lake Superior, 1880, pp. 34–35.

[2] Report of the State Board of Geological Survey, Lansing, 1893, pp. 129–130.

II.

For the purposes of this article it is unnecessary to give a detailed description of the Republic rocks, as their character is sufficiently indicated by the names attached to the several formations in the table below, which shows, with some slight modifications, the divisions, the order of succession, and the nomenclature as determined and used by Brooks, Wadsworth, and the United States geologists, respectively.

I. Brooks.	II. Wadsworth.	III. U. S. Geologists.
Huronian	*Holyoke Formation*	*Upper Marquette Series*
Quartzite XIV.	Quartzite	Quartzite
	Unconformity	Unconformity
Ferruginous Jasper, XIII.		*Lower Marquette Series*
Specular and Magnetic		Specular Jasper
Ore Formations XII.	Republic	Magnetite-Actinolite-
Magnetic Siliceous		Schist
Schist X., VIII., and VI.	Formation	
Quartzite V.		Quartzite and Conglomerate
Unconformity	Unconformity	Unconformity
Laurentian	Cascade Formation	Archean

I have omitted from column I., the succession according to Brooks, the diorites VII., IX., and XI., which are now known to be later intrusive sheets and dikes. That Brooks should have divided the ferruginous rocks between the quartzites V. and XIV. into what we now think an unnecessary number of formations, is easily understood, when it is remembered that his classification was a provisional one for field use, which the exigencies of hurried publication forced him to retain in his final report.

In column III. I have made two divisions of the ferruginous rocks. These are sharply separated in aspect, and in the western part of the Marquette district at least, each has its own place in the stratigraphical column. The specular jasper when present, always overlies the magnetite-actinolite-schists. No theory of difference in origin is implied, and the distinction is entirely one of convenience.

Dr. Wadsworth has not, I believe, published a detailed section of the rocks at Republic.

III.

All the rocks of the Upper and Lower Marquette series have been closely folded in the Republic area into a syncline, about seven miles long, the axis of which runs about northwest and southeast. The present fold for most of its length is sunk deeply into the Archean, the axis being practically horizontal. South of Smith's Bay, however, the axis rises with a pitch of nearly 45°, the several formations swing around successively in horseshoe form through an angle of 180°, from the northeastern to the southwestern side, and the fold, so far as it affects the bedded rocks, abruptly terminates. Through the greater part of the length of the trough the rocks on the two sides of the axial plane have been squeezed nearly into parallelism. On the eastern side, few of the many surface observations show in the upper quartzite a dip less than 80°, which is the average to a depth of more than 900 feet in No. 8 shaft. On the western side the dips are somewhat lower, but will average nearly 80°.

The formations in the unconformably underlying Lower Marquette series on the eastern side of the trough dip at uniformly higher angles, and stand either vertical, or show a slightly overturned dip towards the east. There is then a pretty constant upward convergence of the two series along the contact, averaging perhaps 15°.

The distance in which the turn is made at the southeast end of the trough, or at the bottom as it really is, is relatively very short. The radius of the generalized curve into which the

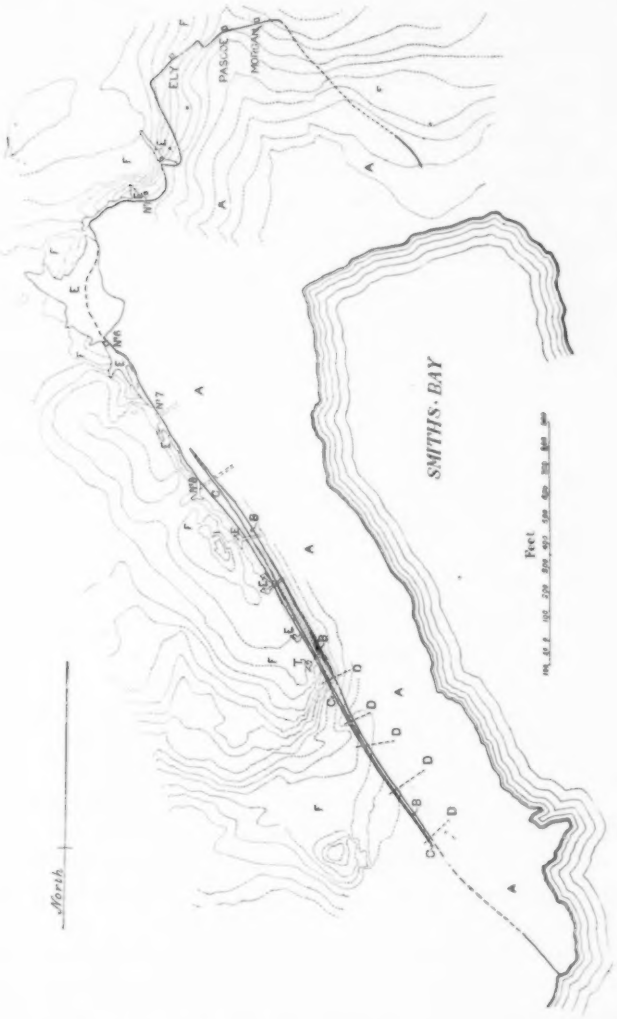

FIG. 1.—The Vicinity of the Republic Mine. A, A = Area underlaid by the Upper Marquette quartzite. B, B = Jasper Wedge. C, C = Quartzite Tongue. D, D = Diamond-drill holes. E, E = Open pits. F, F = Area occupied by the Lower Marquette Jasper. T = Thompson pit. Contours (from Brooks) at ten-foot intervals. The heavy black line is the outcrop of the base of the Upper Marquette Series. When dotted it is covered, or not precisely determinable.

base of the upper quartzite has been thrown, can be very little greater than the thickness of that formation. Field study shows clearly that the neutral surface of the folded material lay below the base of the upper quartzite, and included a considerable portion of the actinolite-schists. This is proved by the severely contorted condition (showing compression) of the thinly bedded jaspers, and by the same structure on a larger scale in the more heavily bedded quartzite. The crowding of the rocks above the neutral surface into a constricted space has resulted in the formation of three important synclines, separated by two anticlines, all subordinate to the main fold. The most eastern of the synclines occurs at the great open pit of the Republic mine; the middle, in the ground opened by the Morgan, Pascoe and Ely shafts; the westernmost in the neighborhood of the Swamp shaft[1] (Fig. 1). These larger subordinate folds are accompanied by a multitude of smaller anticlines and synclines, of various dimensions. They are smaller, more numerous, and more closely compressed in the iron-bearing member than in the overlying quartzite.

The upper quartzite, which is a massive and heavily bedded rock, yielded to the compression by differential movements of one bed over another, and doubtless also by thickening. The effects of the movement of bed on bed are strikingly shown at numerous points in the horseshoe, perhaps particularly well in the small open pit east of the Ely shaft. Here the individual quartzite layers, from one foot upwards in thickness are separated by parallel selvages of ground-up quartzitic material, varying in thickness usually from two to four inches. In the case of one, the measured thickness is eleven inches. These selvages, known locally as a variety of "soap-rock," show frequently a vertical pressure-cleavage.

It is certain, then, that the original sheet of sediments, which varied in character from thinly leaved jaspers below to heavily bedded quartzites above, and aggregated, for the area under discussion, upwards of half a mile in thickness, has been bent back

[1] The Swamp shaft falls outside of the limits of Figure 1.

upon itself, and that the neutral surface of division between the portion above, that was subjected to compression, and the portion below, that underwent tension, lay well beneath the heavily bedded quartzite. The part of the sheet above the neutral surface was confined within a progressively narrowing space, to which it had to accommodate itself by thickening the beds, by plicating them, and also by relative movement of each bed on that below it. That the accommodation thus necessitated by

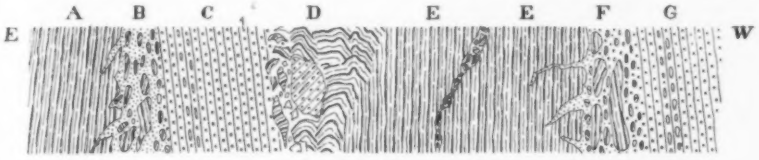

FIG. 2.—Section north of the Thompson Pit. A = Lower Marquette Jasper. B = Conglomerate. C = Quartzite tongue. D = Breccia. E = Jasper Wedge. F = Conglomerate. G = Quartzite. One inch = 20 feet.

the mechanical conditions actually did take the form of slipping along bedding planes, is, in the case of the quartzite, clearly shown.

IV.

I will now consider the quartzite tongue. The best exposures of the conglomerate at the base of the upper quartzite tongue, the included jasper wedge, and the main mass of jasper, including all contacts, may be seen on the natural cross-section afforded by the breaking down of Republic Mountain north of the Thompson pit. This section is represented in Figure 2, and a sketch plan of the outcrops is given in Figure 3. The conglomerate at the base of the main mass of quartzite is exposed on the steep western face of the bluff, from its north end almost to No. 8 shaft. It holds pebbles of jasper, of banded jasper and ore, of ore, and of quartz, which last with ferruginous matter forms the cement. The jasper inclusions are often large and angular, and in many cases it is difficult to see that they are completely detached from the main jasper body of the tongue. The conglomerate cement, which is largely made up of grains of

blue quartz, fills cracks in the underlying aspe wedge, often in directions transverse to the banding (Fig. 4). Some of these cracks may be traced for several feet back from the contact. In many places the general course of the contact cuts the banding of the jasper of the wedge at a considerable angle. Altogether the conglomerate is unmistakably basal, and was clearly laid down upon an irregularly eroded surface.

From this contact for about sixteen feet to the east the jasper wedge comes in. The great mass of this rock cannot be distinguished, either by the eye or under the microscope, from the specular jasper of the Lower Marquette iron-formation. It is very rich in iron ore, the jasper bands often showing the tendency to break up into oval-shaped units that indicates an advanced stage towards concentration. Occasionally, however, within the solid body of the jasper, small patches of quartzite may be observed, which occur singly, or several together along the same general line. These patches are not interbanded with the jasper bands, but often cut them off squarely at their margins (Fig. 5). They recall the sand-pockets which occur similarly in the banded ore at the Mountain Iron Mine on the Mesabi range.[1] Here, doubtless, as there, the sand has been introduced from above, at a time subsequent to the development of the banded structure.

With the exception of these rare quartzite pockets the jasper wedge contains no foreign fragmental material. Through it, however, run several fault lines, which are indicated by narrow breccias, the materials of which are entirely derived from the jasper itself, and by displacement of the jasper bands at the walls. Some of these breccias run nearly parallel with the banding, while others cut across it at considerable angles.

The jasper wedge terminates to the east in a very distinct fault breccia some five feet in width, at its widest point north of the Thompson pit. This breccia consists of large angular pieces of jasper (one measured one by three feet), of quartzite, of quartz and of iron ore, and many pebble-like forms of all

[1] Compare Bulletin No. X., Minnesota Geological Survey, p. 205, Fig. 20.

these, surrounded by more or less ferruginous, chloritic and siliceous cement, in which many grains of blue quartz occur. The jasper wedge is not separated from the breccia by any sharp line of division. The layers, which in the solid body of

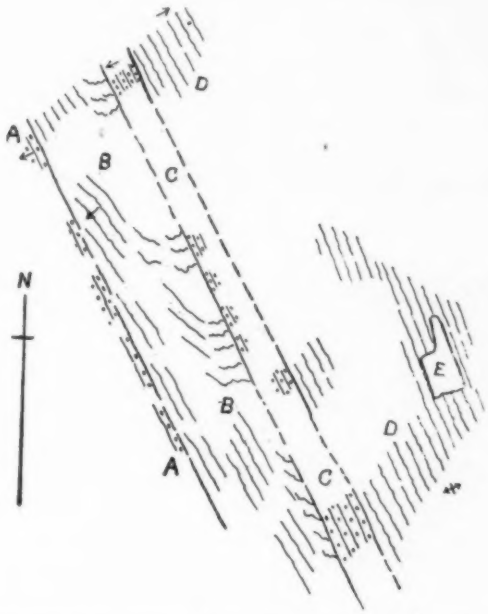

FIG. 3.—Sketch plan of the outcrops in the vicinity of the Thompson Pit. A, A = Conglomerate at the base of the main mass of the Upper Marquette Quartzite. B, B = Jasper Wedge. C, C = Quartzite tongue. D, D = Lower Marquette Jasper. E = Thompson Pit. One inch = 50 feet.

the wedge stand nearly vertical, become contorted near the breccia and bend towards it, the convex side of the little arches being upward on vertical sections and towards the south on the horizontal exposures (Figs. 2 and 3). This indicates that the material west of the fault, towards the interior of the trough moved relatively upwards, and had also a southerly horizontal component.

Next east of this breccia about six feet of westerly dipping quartzite comes in, constituting the quartzite tongue. South of the Thompson pit this quartzite steadily increases in thickness, and in about 300 feet attains a width of twenty-five feet. The quartzite shows the plainest marks of its sedimentary origin, and it is almost incredible that any other could have been attributed to it. It contains thin layers of conglomerate that may be followed for considerable distances. These layers are composed of nicely rounded pebbles of jasper, of specular and magnetic ore and of quartz, as well as of larger flat slabs of banded jasper. Where the quartzite becomes thicker, a little north of No. 8 shaft, the conglomerate layers in the upper portion hold a few pebbles of magnetite-actinolite-schist. In the bedding planes the pebbles have a roughly parallel inclination of 30–40° to the north, which is nearly the general pitch of the trough. A system of parallel normal joints having the same inclination also affects the quartzite as well as the jasper, and seems to have had some influence in localizing ore-concentration, since the small body at the scram immediately north of No. 8 rests upon one of them.

The quartzite tongue is also in places gashed with a parallel system of narrow quartz veins which dip south about 40°, and so are nearly normal to the pitch. These are confined to the massive quartzite, and stop short at the conglomerate layers in it, nor do they extend into the jasper wedge above or into the main jasper body below. It may be that they represent open spaces where the massive quartzite was pulled apart, possibly at existing joints, by the drag of the upper members along the fault.

Below the quartzite on the line of section follow three or four feet of conglomerate entirely similar to the conglomerate which overlies the jasper wedge, and having identical unconformable relations with the specular jasper of the Lower Marquette series, which continues in an unbroken body to the east.

The significant facts along this section (and they are equally evident at many points south), which seem clearly fatal to the

idea that the jasper wedge is an interbedded member of the upper series are these: (1) It is not interbedded. (2) The main body of Upper Marquette quartzite to the west is as clearly separated from the jasper wedge by an erosion interval as the quartzite tongue is from the main body of Lower Marquette jasper upon which it rests. The jasper wedge cannot belong to the upper series unless there are two upper series. (3) The jasper of the wedge is not a fragmental rock, and no contemporaneous fragmental material has been recognized in it. It disappears a

FIG. 4.—Plan showing quartzite filling a crack in the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is ten feet south of the suspended ladder. About one-sixth natural scale.

short distance south of No. 8 tunnel, and the two quartzites come together. If it were a member of the upper series, it must have been laid down at the same time that a rather coarse fragmental rock was being deposited a few hundred yards away, in which case it is hardly conceivable that clastic material should not have been largely included in it.

V.

While the relations of the quartzite tongue are correctly represented on Brooks' map, the better surface exposures of the present day, and the large amount of exploration done by the Republic Company, enable its position now to be fixed with much greater precision. Several diamond-drill holes north of the Thompson pit have shown that it extends 500 to 600 feet north

of the point where it terminates on Brooks' map. It becomes steadily narrower, and as it does not appear at the Kingston and Kloman exposures on the west side of the river, there can be little doubt that it gradually dies out, and that the jasper wedge finally merges into the main body of specular jasper (Fig. 1).

Therefore, the facts to be explained appear to be these: A quartzite tongue branches in the south from the main mass of similar quartzite, and after continuing substantially parallel with it for a long distance, finally tapers to a point in the north in a

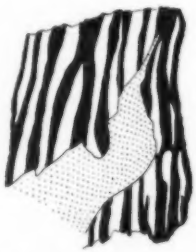

FIG. 5.—Elevation showing part of a quartzite "pocket" in the interior of the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is about 100 feet northwest of the Thompson Pit. About one-twelfth of the natural scale.

mass of specular jasper. The quartzite tongue includes between itself and the main quartzite mass, an exactly similar jasper tongue which starts in the north from the mass of specular jasper, and tapers to a point in the south in quartzite, the two tongues interlocking. The quartzite in each case, in the tongue and in the main mass, has similar and unusual relations (those marking a time-break) with the jasper of the tongue and of the main mass. And between the jasper wedge and the quartzite tongue extensive faulting has taken place.

These facts point towards if they do not demonstrate the identity in age of the two jaspers, and of the two quartzites, and indicate that their present relations are due to faulting.

Recurring now to the mechanical conditions which affected the rocks during the folding, we have seen that the material

above the neutral surface yielded to the compression, in part, by slipping along the bedding planes. If for any reason such movement could take place more easily along any one surface, the neighboring surfaces would be relieved, and one of maximum movement would result. It is readily conceivable that in the same way one local maximum might relieve several neighboring maxima, and so a large amount of movement might be accumulated along a single surface. A maximum movement, starting in the specular jasper would, on account of the slight upward convergence of dip, necessarily tend to cut across the quartzite at the contact. The quartzite might be traversed until a surface of maximum movement in it was reached, which would then be followed. The result would be a fault, along which the material on the side towards the interior of the trough would be displaced relatively upwards, and which, in the direction of the strike, might easily pass from one rock to the other more than once. The wedge of specular jasper included between the surface of movement and the contact surface would move relatively upward with the main body of quartzite, while the corresponding wedge of quartzite above the line along which the contact surface was traversed would remain relatively at rest with the main mass of jasper.

A break formed under such conditions, accompanied by displacement sufficient to bring these two wedges together, and followed by sufficient denudation, would result in the surface relations that may now be observed on Republic Mountain.

HENRY LLOYD SMYTH.

CAMBRIDGE, MASS.

A SKETCH OF GEOLOGICAL INVESTIGATIONS IN MINNESOTA.

PRIOR to the beginning of geological investigations in Minnesota there was a period of exploration and travel, in the published accounts of which are some references to the strictly geological features of the state,[1] and others from which some inferences can be drawn bearing upon the natural features and often upon the geology. Omitting the references made by Champlain in 1615 to the "Grand Lac" and the explorations made by Grosselliers and Radisson between Hudson's Bay and Lake Superior in 1659, and the maps of Franquelin dated 1688, and Beauharnois, dated 1737, it is sufficient here to mention only the discovery of the Falls of St. Anthony by Father Hennepin who accompanied Accault in an expedition up the Mississippi, sent out by La Salle, in 1680. Hennepin's original account of the falls has been used as a datum from which to calculate the amount of recession from their discovery to 1857. This important geological phenomenon was viewed through the eyes of a religious enthusiast, and he named them in honor of St. Anthony of Padua, his adopted patron saint. Sieur Du Luth about the same time was making some additions to the known geography of the state. In 1683 Le Sueur made the earliest examination of the valley of the Minnesota. He mentioned a "green earth," which he supposed to be carbonate of copper, at a point near Mankato, and a large mass of native copper on Lake St. Croix. Jonathan Carver traveled extensively in Minnesota in 1766. He gave a full description and an illustration of the Falls of St. Anthony, which have served to

[1] There is a "sketch of explorations and surveys in Minnesota" in Vol. I. of the final report of the present "Geological and Natural History Survey" of the state. This deals largely with the early explorations. In Bulletin No. 1, of the same survey, will be found some account of the institution and progress of the present survey.

fix their position at that date. He makes the first mention of the red pipestone, or catlinite, of the southwestern part of the state.

Following these early travels was a period of territorial exploration, extending from 1783 to 1858. When the War of the Revolution closed the area which now comprises the state of Minnesota was divided between the French and the United States. From 1783 till the expedition of Lieutenant Z. M. Pike, of the United States army, which took place in 1805, the Upper Mississippi region was left almost as it had been under the British, whose fur-traders still overran the region and still floated the British flag at their trading-posts or "forts." During this period, however, an indefatigable English geographer crossed the northern part of the state and recorded his observations of latitude, depositing his notebooks with the Northwest Fur Company, by whom he was employed, These records have remained unpublished until recently.[1] The work of this geographer, whose name was David Thompson, resulted in determining the fact that the northern source of the Mississippi was not north of the Lake of the Woods, where it was assumed to be by the treaty of 1783. He reached Turtle Lake, the "Julian sources" of the Mississippi, according to Beltrami, twenty-five years before that gentleman saw the lake, and recorded the latitude of the Mississippi at Red Cedar (now Cass) Lake. Lieutenant Z. M. Pike in 1805 measured and described the Falls of St. Anthony. This description, as it is accompanied by a map of the river and cataract, has served to fix the position of the falls at that date. He also described briefly the Falls of Pokegama. In 1871 Major S. H. Long again visited and described the Falls of St. Anthony, giving some notes on the nature of the rocks that cause them. In 1820, and again in 1832, Mr. H. R. Schoolcraft was in Minnesota in the employ of the United States government. He was the first to give a geo-

[1] E. D. NEILL. History of Minnesota, fourth edition, p. 866. Minneapolis, 1882. Mr. J. B. TYRRELL has more recently published these notes in the Proceedings of the Canadian Institute, March (published October), 1888.

logical account of the lower valley of the St. Louis River. The rock at the Falls of St. Anthony he considered Lower Carboniferous; *i. e.*, of the same age as the lead-bearing Mountain Limestone of England. In 1832 he discovered the source of the Mississippi River and named it Lake Itasca, an imaginary name of an imaginary Indian divinity, constructed by him for the occasion from the two Latin words *veritas*, truth, or true, and *caput*, head, by taking two syllables of the former and one of the latter. By this he intended to indicate that Lake Itasca is the *true head* of the Mississippi. Beyond this signal discovery and a picture of the Falls of St. Anthony, Schoolcraft added but little to the geography or geology of the state. He should, however, have credit for noting the occurrence of crystalline rocks at several points in the Mississippi River below the Falls of Pokegama.

Keating's narrative of Major Long's expedition in 1823 to the source of the St. Peter's River contains much on the geology of the route. Besides an account of the Falls of St. Anthony, Professor Keating gives the first geological description of the valley of the Minnesota River (then called St. Peter's) and of the *coteau des prairies*. Descending the Red River of the North to Winnipeg, this party turned eastward, crossed the Lake of the Woods, ascending Rainy River and Rainy Lake, thence following the international boundary line to the east end of Sturgeon Island where they turned more northward, in order to reach Fort William by another route. Keating was a chemist and a mineralogist, and his notes on the crystalline rocks of the route afford the first instance of the application of the correct and careful methods of modern science to the investigation of the geology of the state. It was a reconnoissance simply, and but few facts could be noted, but such as they are they have been found, in the main, to be reliable.

Lieutenant James Allen, who accompanied Schoolcraft in 1832, rendered an independent report of the expedition, in which he gives brief descriptions of the topography and general features, including the dalles of trap-rock on the St. Croix river.

G. W. Featherstonhaugh was the first professional geologist, so far as known, who made the state a visit. He was an English gentleman and was commissioned "U. S. Geologist" by Col. J. J. Abert, of the bureau of topographical engineers. He was accompanied in 1835 by Mr. W. W. Mather who afterwards became known as a geologist of the state surveys of Ohio and New York, but they parted by reason of some disagreement, and Mather returned alone from some point on the upper waters of the Minnesota river. It is possible that Mr. Featherstonhaugh's geological report suffered materially in thus being deprived of the services of Mr Mather who retained his geological notes. The manuscript of Mr. Mather, not published, was said to have been in existence for some years after the report of Mr. Featherstonhaugh was issued, but for many years it has been lost. Mr. Featherstonhaugh's report, published at Washington, was largely a general treatise on geology, but contains many new and interesting facts relating to the physical features of the country, including an account of the Falls of St. Anthony. He visited the place of Le Sueur's "copper mine," but concluded that the discovery of copper, as reported by Le Sueur, was one of those fables which the early French travelers sometimes invented in order to gain influence at the court of France. The "Carboniferous limestone" he supposed to extend as far as the bluffs of the Minnesota at Mankato. He ascended the *coteau de prairie*, but he failed to visit the red pipestone quarry situated in the extreme southwest corner of the state.[1]

It remained for George Catlin, in 1836, to bring away from its native place, a sample of the red pipestone. This was submitted to Dr. C. T. Jackson, of Boston, who after analysis and description, gave it the name of catlinite.

Joseph Nicolas Nicollet,[2] from 1836 to 1843 prosecuted geo-

[1] Mr. Featherstonhaugh's report is entitled: "Report of a geological reconnoissance made in 1835 from the seat of government by the way of Green Bay and Wisconsin territory to the *coteau des prairies*, an elevated ridge dividing the Missouri from the St. Peter's River," printed in 1836.

[2] Additional facts about Nicollet. H. V. WINCHELL, American Geologist, Vol. XIII., p. 126, Feb., 1894.

graphical researches in the Northwest. Incidentally he aided greatly in determining some parts of its geology. It was through him that T. A. Conrad obtained fossils from the lead-bearing formations of the Upper Mississippi by which he, first of all, correctly assigned that limestone to the age of the Trenton of New York.[1] Professor James Hall, but little later, examined it in the field, and came to the same conclusion.

The chief event connected with the territorial investigation of the geology of Minnesota was the survey of D. D. Owen, extending from 1847 to 1850, which also covered much contiguous territory. This survey had the resources and the corps of men which enabled it to pronounce finally on some of the mooted questions of the geology of the Upper Mississippi valley, and it was continued long enough to complete at least a reconnoissance of a large area. Its fine quarto volume,[2] published at Philadelphia by Lippincott, Grambo and Co., contains, besides the report of Dr. Owen, reports by J. G. Norwood, B. F. Shumard, C. Whittlesey and R. Owen. It embraces also a memoir by Joseph Leidy on the extinct mammalia and chelonia of Nebraska Territory, and several valuable appendixes. Dr. Owen's other assistants were J. Evans, B. C. Macy. A. Litton, G. Warren, H. Pratten, F. B. Meek and J. Beal. From this report may be said to date the systematized geology of the state. It laid accurately a broad base on which all future geologists of the state must build. About this time the New York State survey was in vigorous action, and some of its results had been published. Hall, Conrad, Emmons, and Mather, with Hitchcock of Massachusetts contributed indirectly to the final conclusions at which Dr. Owen arrived. The form of the volume is similar to that of the final report of the New York survey, but its breadth of scope is greater and its typographic execution superior. Its illustrations

[1] Observations on the lead-bearing limestone of Wisconsin and descriptions of a new species of trilobites and fifteen new Silurian fossils. T. A. CONRAD. Proc. Acad. Nat. Sci., Philadelphia, Vol. I., 1841–43.

[2] Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and incidentally of a portion of Nebraska territory, by DAVID DALE OWEN, United States geologist, 1852.

and its maps are first-class. It is a well-known work, and can still be seen sometimes offered for sale by dealers. It constituted at that time one of the largest and most expensive publications of the United States government, a monument at once to the learning, the zeal and the wise management of Dr. Owen. It is not necessary here to go into the scientific merits of this volume, since its contributions to the geology of Minnesota and of the Northwest are well known and have entered into the geological literature of the country in many forms.

After this territorial period, ending in 1858, the new state made early attempts at a geological survey, but met with poor success. The first legislature ordered a reprint of portions of the geological report of Professor Daniels on the survey of Wisconsin, Minnesota having formerly been embraced in the territory of Wisconsin. The second legislature instituted a plan for establishing a thorough survey. Messrs. Charles L. Anderson and Thomas Clark were appointed commissioners to report on the geology of the state and on a plan for such survey. They rendered a report the following year, making an octavo pamphlet of twenty-six pages, outlining the proper scope and methods of such a survey. But the legislature took no action, probably because of the objections of Governor Ramsay who considered that the state was not able at that time to bear the cost which the survey would entail. In 1864 a law was passed by the sixth legislature authorizing the governor to appoint and direct a state geologist. The first appointee under this law was Dr. Aug. H. Hanchett. His assistant was Thomas Clark. But little or nothing of value was done by Dr. Hanchett, but Mr. Clark rendered a report of seventy octavo pages on the physical features of that portion of the state bordering on Lake Superior. The next two years the survey was conducted by Mr. H. H. Eames who had his brother, Richard M. Eames, for assistant. Two small annual reports were rendered by Mr. Eames, who was devoted to prosecuting a "mineral hunt" in the northern part of the state. This was apparently in accordance with instructions from Governor Miller. Excitement soon arose over the discov-

ery of small amounts of gold in the schists at Vermilion Lake, and a genuine "boom" (so-called in later years) centred on that region. Much prospecting was done and much money squandered, but little geology resulted from these two years of the administration of Mr. Eames. The state survey collapsed ingloriously, and was not revived till the commencement of the present survey in 1872.

From other sources, however, the geology of Minnesota was kept in a state of progress. Professor James Hall visited the state in 1865, and examined the St. Croix valley with reference to its prospects for copper in the vicinity of Taylor's Falls. This visit was prolonged for the purpose of examining the reputed coal beds of southwestern Minnesota which he found to belong to the Cretaceous system. The next year a report of the trip to the southwestern part of the state was made by Professor Hall. It is published in the Transactions of the Philosophical Society of Philadelphia. This paper embraces the first geological observations ever made on a very large area in the region southwest from the Minnesota River, and may be said to have supplemented and extended the observations of Keating and of Featherstonhaugh. In 1866 also were published the field observations of Colonel Charles Whittlesey made in northern Minnesota in the years 1859 and 1864. These also embodied some more detailed descriptions of the region north of Pokegama Falls, resulting from the survey of D. D. Owen, whose assistant Whittlesey was. The papers of James Hall and of Charles Whittlesey constitute the most valuable contributions to the geology of the state during the period following the territorial exploration, and preceding the present survey. There were, however, some later surveys. One was a topographical survey of the Minnesota valley by General G. K. Warren, under the United States government. His reports are to be seen in the Report of the Chief of Engineers for 1867, 1868, and 1874. He first published, with full demonstration, the idea that the valley of the Red River of the North was formerly covered by a freshwater lake which embraced the region of Lake Winnipeg. Professor Henry Youle

Hind had already announced such a hypothesis, but General Warren mapped the area of the lake and assigned a cause for the former drainage toward the south.[1] In 1871 Messrs. W. D. Hurlbut and J. H. Kloos contributed to the geology of Minnesota, the former in the southern part of the state and the latter in the northern. Their papers were published in the *Minnesota Teacher*, although Mr. Kloos contributed an article, in 1872, to the *American Journal of Science*, giving particulars of the discovery of Cretaceous beds with lignite in the valley of the Sauk River, adding palæontological determinations by F. B. Meek.

Professor A. Winchell was appointed by Governor Horace Austin in 1871 to make an examination of the vicinity of Belle Plaine, in Scott county, where indications of brine were said to exist. This was in accordance with an Act of the Legislature of 1870. The report was printed by the Legislature of 1872. It gives a sketch of the geology of the region, including notes on the drillings from the Belle Plaine well, and concludes that probably brine does not exist at Belle Plaine, nor in the rocks below.

The present survey.—The law of the present survey was approved by the governor, March 1, 1872. It is the first instance in which a systematic survey has been placed by any state of the Union, under the direction of the regents of the State University, with requirement to make constant examination and stated reports. It has often happened that the professor of geology in a state institution has been the state geologist, but in those cases he has been directed by some other state board or by the governor. The arrangement which prevailed in Alabama, during the incumbency of Professor Tuomey, of the State University, was in some respects similar, but it was not inaugurated at the instance of the state legislature. It was an incident of his professorship as ordered by the trustees,[2] and when it was recog-

[1] See the American Naturalist for November, 1868.

[2] E. A. SMITH, Geological Surveys in Alabama. JOURNAL OF GEOLOGY, Vol. II., p. 275.

nized by the legislature the explorations were still carried on at the expense of the University of Alabama. When the state later appropriated money to conduct the survey, Professor Tuomey resigned his position in the university. The present survey of Alabama was instituted by law in 1873, although the trustees of the university had required the professor of geology the year previous to revive the plan which was established under Professor Tuomey. The survey as such is not under the direction of the university trustees. The governor, the secretary of state, and the state geologist constitute the board of control.

The plan of the Minnesota survey was recognized at once as a new departure and was thus referred to by a high authority:[1]

"We spoke in the June number of the *Popular Science Monthly* of the advantages that would arise from connecting the scientific exploration of the several states with their higher educational institutions. We have been since reminded that this is an accomplished fact in at least one of the states, and we hasten to give credit to Minnesota for having taken this new departure in scientific education. It is one of the youngest states in the Union, and a generation ago was but a land of savages, an indefinite tract in the great "Northwest Territory," beyond the "Wisconsin," beyond the distant Mississippi, that we now see taking the lead of the older states in organizing the new education by devoting her university to the comprehensive and practical study of nature. This step has been but recently taken, and its benefits are prospective, but if thoroughly carried out there can be but little question of the advantages that must arise to the people of the state. . . . . The movement in this case, it is evident, has been initiated mainly in the interest of the geological survey, but it is to be hoped that the larger objects of education to which it is a means will not be lost sight of. The university will undoubtedly be benefited by taking the responsibility of the work, but the movement will fall greatly short of the good it might accomplish if it is not vitally connected with the educational system of the state."

This survey has been in uninterrupted progress under its original law from the date of its establishment to the present. It requires the regents not only to conduct a purely geological survey, but also to make a natural history survey, including botany and zoölogy, to construct a topographical map of the state, and to investigate its meteorology. The law establishes a

[1] Editorial in the Popular Science Monthly, Vol. III., p. 391, 1873.

museum at the university, which is ordered to be kept in good order and accessible to the public, and provides for the exchange of specimens with other institutions. This law was drafted by President W. W. Folwell, of the University of Minnesota, and is still in force in all its provisions. It was introduced in the Senate by Hon. J. S. Pillsbury, of St. Anthony. The legislature has sometimes passed supplementary laws to facilitate the execution of the main law, or directing the methods of publication of the survey reports, but has in no way changed the original law.

To accomplish this survey *an annual appropriation of one thousand dollars was made by the legislature!* The writer was appointed to conduct it in July, 1872, and tendered his first report December 31, 1872. The funds being so meager, the state geologist was required to earn the greater part of his salary by teaching the natural sciences in the State University, and he held the chair of geology and mineralogy and discharged all its functions, in addition to the work of the survey, until 1878, when the regents made other provision for such instruction. It is apparent, on the slightest consideration, that a state survey based on such a fund would go so slowly that more than a century would lapse before its completion, and that it would not be apt to receive the respect of the people, nor maintain its rank amongst such enterprises. In casting about for some means to establish the survey on a better footing, the writer, when engaged in the field work of the first year's campaign, was much with Hon. W. D. Hurlbut, of Rochester, Minn., and received from him the suggestion that the state lands known as Salt Spring lands, might be made to support the survey. This United States land grant had been the prey of various chimerical schemes for developing imaginary natural resources, and it appeared evident that it would be entirely absorbed by unprincipled and ambitious designers unless it were taken care of by the legislature in such a way as to put the lands beyond their reach. The suggestion of Mr. Hurlbut may have resulted from conversations with the state auditor, Hon. O. P. Whitcomb, who was his townsman, and who was also

friendly to the survey. It is probable, further, that the auditor had conferred with Hon. A. J. Edgerton, then state railroad commissioner, and with the senator (Pillsbury) from St. Anthony, as has been claimed, and that there was, prior to the writer's knowledge, a concerted agreement to devote these lands to the support of the survey.[1] However that may be, the first report of the survey presented the suggestion to the legislature that these lands could be devoted, consistently with the terms of the United States grant, to the maintenance of the survey ordered by the previous legislature. The law that was passed turned these lands over to the custody and control of the regents of the university, with instructions to sell them and devote the proceeds to the support of the geological and natural history survey. Thus the survey was put on a financial basis which promised for it a reasonable duration. When later it was found that there was a large deficit in these lands due to the negligence of the United States officers, and the state was allowed to make re-selections in other portions of its domain, and when such re-selected lands were also devoted by the state to the same purpose, the fund became sufficient, with economy, to keep the enterprise in working activity for several years, and apparently to complete the geological portion. These lands, thus augmented, amounted to 38,643 acres, which could not be sold, according to existing law, for less than five dollars per acre.

In addition to this financial foundation the legislature increased the annual appropriation named in the original law to two thousand dollars, the same to continue until the annual proceeds from the Salt Spring lands should amount to that sum. It was discontinued in 1879. As the sales of the Salt Spring lands did not furnish sufficient revenue the survey became indebted to the university. The legislature, in 1887, appropriated ten thousand dollars. In 1891 it appropriated fifteen thousand dollars, and in 1893 ten thousand dollars.

[1] The writer gives these details because some complaint has reached him that due credit had not been given by him, in an earlier account, to the prior conferences of these public officials.

TOTAL COST OF THE MINNESOTA SURVEY.

Annual appropriations at the commencement of the survey, -	$15,000.00
Proceeds of the Salt Spring lands to July 31, 1888, - -	46,105.07
Legislative appropriation, 1887, - - - - - - -	10,000.00
" " 1891, - - - - - - -	15,000.00
" " 1893, - - - - - - -	10,000.00
Proceeds of the Salt Spring lands from July 31, 1888, to July 31, 1892, - - - - - - - - - - -	27,621.09
Total, - - - - - - - - - - -	$123,726.16

This covers the expenses of all departments of the survey, which lately has been rendered more active in the lines of botany, zoölogy, and topography than formerly. It also embraces the expenses of the museum and the library, and includes $12,510.80 expended for the department of instruction in the university prior to 1878. It does not cover the cost of publication of the reports and bulletins. These are executive documents of the state, emanating by law, from the State University, and their publication is provided for by estimates for public printing which are presented to each session of the legislature.

The field work of this survey began in the southern counties and progressed northwardly. But little technical work was attempted at first, the aim being to render work done, as expressed in the reports, acceptable to the people of the state, and thus to the legislature on whose good-will the firm establishment of the enterprise depended. Quicker geological returns were possible in the southern and central counties, which are principally of prairie and settled, than in the northern, which are forested and were then largely in their primeval state. Still the annual reports do not record a steady progress northward, but embrace miscellaneous and often unclassified matter derived from all parts of the state. They average about 250 pages octavo, and have many illustrations. Twenty-two annual reports have been issued. In 1884 the first volume of the "final report" required by the law of the survey, was issued. It is a quarto of 700 pages and 43 plates. It embraced the work of about ten years, so far as it could be made conformable with the plan of

publication adopted. The second volume of the final report, of the same size and style as the first, was published in 1888. This covered subtantially the central third portion of the state. These volumes contain no palæontology, but are devoted to a description of the geological features, with frequent references to the economic resources of the areas described. The state is being mapped by counties, and each chapter of these reports is accompanied by a colored and contoured map of the county it describes. There is to be no large atlas in sheets three or more feet square, but a book-atlas, in quarto size, will constitute one of the final volumes, made up of all the county maps, or plates, with brief descriptive text for each. The third volume of the final report has been under way for two or three years. It is devoted to the palæontology of the Lower Silurian, *i. e.*, the formations above the St. Peter sandstone and up to and including the Galena limestone. If there be no interruption of the survey, it will be concluded in the same style by the publication of one other volume (fourth) of the final report, which will present the geology and lithology of the northern part of the state.

In addition to the annual and the final volumes a third serial is maintained, appearing in independent parts at irregular intervals, embracing more carefully considered investigations, which arise in the progress of the general research, which, yet, cannot be accepted as finished, but ought to be preserved. Of these occasional publications, which are called "bulletins," ten have been issued, and the eleventh is in preparation.

The administration of the survey, in all its departments, was, till 1891, in the hands of the writer, but at that date the botanical, the zoölogical, and the topographical departments were erected into independent surveys, and different members of the faculty of the university were appointed to conduct them. It has been the policy of the writer to conduct the survey, as far as possible, in the interests of the people of the state, in the immediate and economical sense. The plans that have been adopted have been almost always submitted to the regents, or their executive committee, prior to their execution. In some instances

certain public or widespread want for information, expressed in correspondence, or in the public press, such as the demand for information concerning the grasshopper plague and the ways and means for alleviating the evil, the call for peat fuel on the woodless prairies, the ravages of insects injurious to horticulture, the general belief in the existence of coal in the state, the demand for authoritative statements founded on scientific data touching the nature and extent of our forests, or the quality of our soils, or the probability of brine for the manufacture of salt, or the existence of the necessary conditions for artesian water or burning-gas, or the quality of our native building stones, or the extent of iron ore deposits and their qualities,—these have all been elements that have influenced the plans formed from year to year. While answering these purposes as nearly as possible, the survey has been rendered useful to numerous individuals by private correspondence, preventing the useless expense of misguided exploration in many instances, and directly influential in promoting economic industry in every case where its aid was solicited and its data could be employed.

In this policy the usefulness of the survey has been brought home to the people of the state, and they have come to regard it as an indispensable adjunct to the university and to the progressive development of the state in its natural resources. This course was politic as well as just. There was nothing more evident, when the survey began, than that it must have the confidence of the people. The people then lived largely in the southern and central portions of the state. The annual reports embraced common, patent facts, and description cast in a semi-scientific mould. As the survey became grounded in the good-will of our own citizens, it was strengthened for doing more advanced work, and at the same time it found a constituency ready to welcome more scientific publications. It is highly probable that if such a moderate course had not been pursued, the legislature, instead of always manifesting a good-will and determination to have the work well sustained, would have refused the financial aid that has been asked of it, and the enterprise

might have had the short-lived existence that has been the fate of so many other state surveys.

Coöperation of the U. S. Coast and Geodetic Survey.—Under a law of Congress, passed many years ago, the Coast and Geodetic Survey coöperated with such states as had either geological or topographical surveys in progress. This aid consisted in the determination of the latitude and longitude of certain points and the establishment of others by triangulation preparatory to correct mapping. Through the agency of Governor L. F. Hubbard, in 1884, this matter was brought to the attention of the Superintendent of the Coast and Geodetic Survey, and this law of Congress was made operative for the State of Minnesota, and has continued so to the present. That furnished the commencement of the topographical survey which the state law orders. By the combined operation of these laws such triangulation and other field work is authorized as will eventuate in a complete topographical mapping of the state in the most approved methods. This articulation between the two surveys was practically established by Major C. O. Boutelle, an officer of the Coast and Geodetic Survey, and the subsequent conduct of the survey has been under the direction of Professor W. R. Hoag, of the University of Minnesota. This plan not only carries on, with little expense, the required topographical survey, but furnishes to the department of engineering in the university an object lesson in the use of the nicest instruments and some employment for its advanced engineering students—for in all departments of the state survey the law requires the employment of the professors and students of the university when they can be found competent.

The scientific progress of this survey it is not necessary to enter upon, and the writer might not be the best judge if he should attempt to set it forth. Its reports are widely distributed, and its agency, such as it is, in the recent development of the geology of the state, and of the Northwest, is well known.

Conclusion.—It is the custom to "finish" such surveys, but no one who has been cognizant, for twenty years, of the incompleteness of the work which such surveys have to be satisfied

with, and who reluctantly relinquishes from time to time some line of research, or some unsettled problem, in order to devote his energy to the passing events of the general work, will be willing to employ the word *finish* in any other sense than that his time and resources are exhausted, and he must hasten to put in order such data as he may have gathered, ere they be lost by the limitations of human life. Every such survey constitutes a stepping-stone, and only a stepping-stone, to the *finishing* of the geology of the area surveyed, but the end is in the far future, and perhaps in the infinite future. The future stepping-stones toward that end may not be in the manner of formal surveys; but in many ways now unknown, largely through the activity of the professors in the various state institutions who will wrestle with the problems now left unsolved, the intricacies of the geology of the state will be explained more fully. More enlightened public sentiment will furnish multiplied ways and means for more minute work, and the increase of exact knowledge, combined with greater demand for scientific data, will yet carry the geology of the state to a degree of exactness of which we at present can have but a faint conception.

N. H. WINCHELL.

STUDIES FOR STUDENTS.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.

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Definition of the drift. The northern part of the United States, as well as a large part of the Dominion of Canada, is covered by a mantle of incoherent materials composed of clay, sand, gravel and bowlders. These various materials are sometimes intimately commingled, and sometimes more or less distinctly separated from one another. The separation may be either lateral or vertical. One region may be covered by well-assorted gravel or sand, while a contiguous area may be covered by bowlder-bearing clay, or by an unassorted mixture of bowlders, gravel, sand and clay; or layers of sand and gravel may alternate with layers of unassorted bowlder-bearing material in the same vertical section. Where bowlders, gravel, sand and clay are associated without trace of separation or arrangement, any one of them may predominate over the others

to any extent, or all may be commingled in approximately equal proportions.

Through this mantle of unconsolidated material the underlying rock often projects. Many natural and artificial sections likewise reveal the rock beneath. From these sections, and from the general relations of the drift to the underlying rock, it is seen that the surface materials are not restricted to any particular sort of rock. They occur on limestone, sandstone, shale, gneiss, granite, or any other sort of rock, with apparent indifference.

Another feature which at once attracts attention is the fact that the body of material overlying any particular kind of rock contains many fragments or bowlders of rock which could not have been derived from it. Where the underlying rock is limestone, bowlders of gneiss, granite, sandstone, or diabase are often found in abundance in the overlying mantle of loose materials. Such bowlders cannot be supposed to have come from the disruption of the limestone, for limestone does not contain the materials of which they are composed. In like manner, the covering of unconsolidated material which overspreads the surface of gneiss within the area specified, often contains bowlders from a great variety of other formations, such as limestone, sandstone, and shale. Disintegration or disruption of the gneiss could by no possibility have given rise to limestone or sandstone or shale, since gneiss contains nothing from which these rocks could come by any simple process of disintegration or disruption. Not only does the composition of the loose materials overlying the solid rock in the northeastern part of the United States forbid the idea of their origin by the decay of the underlying rock, but in addition to this, the physical condition of the bowlders has a like significance, since many of them show no signs whatever of disintegration. They often look as fresh as if quarried but yesterday from their parent formations.

This aggregate of surface material which overlies different formations indiscriminately, and which is composed of materials which could not have been derived wholly from the underlying rock, is called *drift*. It was long since recognized that the mate-

rials of which it is composed did not originate where they now lie, and that, in consequence, they sustain no definite genetic relationship to the formations of the territory over which they are spread. Long before the drift received special attention at the hands of geologists, it was believed that it had been transported from other localities to those where it now occurs. The early conception was that it had been brought or "drifted" to its present position from some outside source by means of water. It is to this conception of its origin that the formation owes the name *drift*. In the early days of geology this surface material, which often effectually conceals the rock beneath, was regarded as uninteresting in itself, and an obstacle to the study of the underlying formations, which were regarded as the proper field of geological inquiry. So long as the drift was looked upon in this way, it received but little attention; but within recent years it has been the object of critical investigation, and there are now few departments of geology which are attracting a larger share of professional attention, and few departments which have yielded, or are yielding, more interesting and more important results. The accessibility of the drift, and its importance in shaping the details of the surface throughout so wide an area, have made it a favorite subject of study for a large number of students.

Thickness of the Drift.

In general. The thickness of the drift varies greatly. Over large areas its depth is so slight and so unequal that the underlying rock is frequently exposed. This is much more generally true in mountainous and hilly regions than in plane ones, though regions are not wanting where frequent rock exposures are associated with a topography of but slight relief. The mountains of New England, the Adirondacks, the Catskills, the Highlands of Northern New Jersey, and the adjacent parts of New York and Pennsylvania, may serve as examples of mountainous regions where the underlying rock is but poorly concealed by the mantle of drift. Areas of plane or gently undulating topography where the drift is so thin as to allow the underlying rock to be exposed

frequently are by no means rare in the drift-covered area, but within the area of the United States, they are not generally of great extent.

Over wide areas the drift is so thick that the underlying rock is rarely seen except where natural or artificial excavations of great depth have been made. In such cases, excavations afford the only means of knowing the thickness of the drift. In still other regions the covering of drift is so massive that even the deeper valleys and the wells fail to penetrate it to its base. Over considerable areas in Northwestern Minnesota, for example, the older formations are so deeply buried by the drift that they have not been reached by the deepest excavations and borings that have there been made, though this does not mean that they are beyond the reach of deep borings. The drift is also very deep in many parts of Iowa, Illinois, Indiana, Ohio, Michigan, and New York. Depths of something more than five hundred feet have been recorded in a few places. Such thicknesses are rare; but thicknesses of two hundred or three hundred feet are by no means uncommon. The average thickness throughout the drift-covered area is much less, but no very accurate estimate can be made on the basis of present knowledge. The average thickness for the Upper Mississippi basin has been estimated to be not less than 100 feet.[1] For the eastern part of the United States, this figure is probably much too high.

The variations in thickness may be great within short distances. One hill may have barely drift enough to cover the rock, while the next may be composed of drift from base to summit. The drift may be thin on the hills, and deep in adjacent valleys, or, less commonly, the reverse may be the case. Thicknesses varying from nothing to one hundred or two hundred feet are not rare within a single square mile, and sometimes occur within much narrower limits. The natural sections exposed along the sides of valleys, and along the cliffs of seas or lakes, sometimes illustrate the abruptness of the variations in thickness. At one point along the course of a river valley the total face of

[1] CHAMBERLIN: Geikie's "The Great Ice Age," 3d edition, 1894.

the bounding bluffs, scores and perhaps hundreds of feet in height, may be of drift, while at adjacent points close at hand the entire faces of the bluffs may be composed of rock alone, or of rock no more than drift-coated. It follows that the surface of the subjacent rock is sometimes very uneven, and that its irregularities do not always stand in definite relation to the present topography. Where extensive excavations are favorably situated, it may sometimes be shown that the roughnesses of the rock surface beneath the drift are due to the existence of deep valleys excavated in the rock surface before the drift was deposited, and that these valleys do not now appear at the surface because they have been filled by the drift, and thus obliterated as surface features. Since the deposition of the drift, the rain and the rivers have in many places carved out new valleys in its surface. Sometimes these valleys, developed since the deposition of the drift, have sunk themselves through it, and into the rock below.

While abrupt variations in thickness characterize the drift of certain regions, and especially regions of considerable relief, they are not universal. Over large areas its thickness is nearly uniform. This is more likely to be true in plane areas than in areas of marked relief. If the thickness of the drift be approximately uniform in flat regions, it follows that the surface of the underlying rock must be approximately level. Where the depth of the drift is uniform, or nearly so, it may be scores or even hundreds of feet, or it may be very slight, affording no more than a thin soil and subsoil. It is even true, now and then, that areas a few or many miles in extent are nearly free from drift within the very heart of larger tracts, which, with these exceptions, are deeply covered. While the thickness or thinness of the drift is measurably independent of both altitude and topography, it is rather more commonly thick in low and nearly level regions than on high and rough areas. Apart from all considerations of altitude and topography, the distribution of thick bodies of drift is not altogether fortuitous. Regarding the drift sheet as a unit, its greatest average thickness is neither at its extreme edge nor at its centre, but somewhere between the two positions and

distinctly nearer the former than the latter. This is not to be construed to mean that the drift is not often thick both without and within the zone here specified, or that it is never thin in this zone.

Any theory of the drift must take account of these facts. The agent or agents to whose activity it is to be attributed must have been able to leave many small patches, not always higher or lower than their surroundings, essentially without drift. They must have been such as could have left the drift now in thick beds, and now in thin, over limited or extensive areas, without close dependence on topography or altitude, yet without complete independence of either.

Thickness of the drift along its borders. At its margin, the drift sometimes thickens so as to constitute a considerable ridge. This is the exceptional condition of things rather than the general. In other cases the drift grows thinner and thinner toward its edge, its limit being still well defined, and constituting a definitely traceable line. In still other cases the drift feathers out at its edge, ceasing to exert any observable influence on topography. In such cases the border may become so ill defined that it is traceable only with difficulty.

Driftless Areas.

Besides the many small patches of bare or nearly bare rock over which the drift forces acted without leaving deposits of much thickness, there is, far within the outermost limit of the drift-covered country, an area several thousand square miles in extent, where drift is altogether absent. This area lies mainly in southwestern Wisconsin, but embraces small adjacent areas in Illinois, Iowa, and Minnesota. The absence of even a meager coating of drift from this area has led to the conclusion that the agency or agencies which produced the drift were not here operative. There is probably a second, smaller driftless area, also, in the axis of the Mississippi basin, occupying a part of the elevated land between the Illinois and Mississippi rivers, near their junction. This area is much nearer the border of the drift, and appears much less anomalous than the other. Neither of the driftless

areas are notably higher or lower than their surroundings, though both are notably rougher.

In considering the origin of the drift, we are forced to exclude as the sole or principal agents such as would not allow the existence of driftless areas, neither notably higher nor lower than their surroundings, within the very heart of the great sheet of drift.

Constitution of the Drift.

Physical heterogeneity. It is certainly a striking fact which confronts us when we see huge bowlders, sometimes many tons in weight, imbedded in earthy material as fine as that which our most sluggish streams are carrying in suspension. Between these extremes of coarseness and fineness, there are materials of all grades. The proportions of coarse and fine materials are not at all constant. The fine may predominate at one point, the coarse at another. From predominance of fine to predominance of coarse the changes may be abrupt, and frequently repeated. Any one of the constituents of the drift—bowlders, gravel, sand or clay—may predominate over any or all the others to almost any extent. It follows that any one of these may nearly or quite exclude the others, though the drift is rarely composed of large stones only. While, therefore, the drift is remarkable for its physical heterogeneity, and while this heterogeneity is a general characteristic, still there are localities where it is not extreme. There are localities, indeed, where the drift is remarkably homogeneous. In such cases its constituents are more commonly fine than coarse, and rather more commonly of sand than of clay, although drift made up principally of the fine, earthy material which is popularly called "clay," is by no means rare.

From the physical heterogeneity of the drift, it is clear that the agent or agents to which it owes its origin, or to which at any rate much of it owes its origin, must have been able, under some conditions, to carry and deposit at one place and at one time, materials as fine as the finest particles of silt or mud, and bowlders many tons in weight, while they were competent, under other circumstances, to make deposits of much less extreme diversity.

Lithological heterogeneity. The drift of any given area generally contains pieces of some such assemblage of rocks as the following: shale, sandstone, limestone, quartzite, gneiss, schist, porphyry, diabase, and gabbro. Not all these types of rock are represented in the drift of every locality, and some localities contain rock fragments of other types. But if all the foregoing kinds of rock are represented in the drift of a given locality, the drift containing them cannot be looked upon as possessing unusual lithological heterogeneity. Any type of rock represented in the drift may be represented by masses as large as the largest bowlders which the drift contains, and, at the same time, by the smallest particles which will allow of identification. In other words, the physical heterogeneity of any given sort of rock represented in the drift may be about as great as the physical heterogeneity of all.

The various types of rock represented in the drift of any locality are not generally in equal proportions. It is often true that some one type predominates, and this predominance is often striking. But in spite of this, the lithological heterogeneity of the drift is a well-nigh universal characteristic. Any hypothesis which essays to explain its origin must take account of this fact.

We must suppose that the granite of the drift came from some place or places where granite is the native surface rock, since we know of no other possible source for it. We suppose that the shale, sandstone, and limestone of the drift came from regions where shale, sandstone, and limestone severally occur, as the uppermost formations beneath the drift. But so many sorts of rock as frequently occur in the form of loose bowlders in the drift of a given place, do not often occur as surface formations in closely contiguous localities. Within the area covered by the drift there are rarely more than a limited number of rock formations appearing at the surface in closely associated areas. From its lithological heterogeneity, therefore, we must conclude that the sources of the drift were various and wide-spread; and if we conclude that its sources were wide-spread, we have no

alternative but to conclude that the agencies which were concerned in its production were capable of wide-spread action.

Not only do we conclude from the lithological heterogeneity of the drift that it came from wide-spread sources, but we may reach positive conclusions concerning the minimum areal limits of these sources. By a careful study of the lithological character of the stones of the drift at any given point, and by comparing them with the formations of solid rock in all directions from this point, it is generally possible to determine the exact formation from which many of them came. If the surface exposures of the formations from which the identifiable bowlders came be very small, we are able to draw definite and positive conclusions concerning both the direction of transport of the bowlders in question, and the distance which they have journeyed. If the surface exposures of the formation whence they came be large instead of small, the conclusion which could be drawn would be confined within less narrow limits.

If the determination of the direction and distance of transport rested on the identification of a single type of rock, it would be necessary, in order to make the conclusion absolute, to prove that there is no second source, seen or unseen, whence the given type of bowlders could have come. Manifestly this might be a very difficult thing to do. But if identity can be established between various and diverse types of rock found in loose pieces in the drift of a given locality, and an equal number of formations in beds or *in situ* elsewhere, the case becomes much stronger, for it is almost beyond belief that two complex but lithologically dentical series of rock formations, embracing bowlders of so many types as frequently occur in the drift, exist in different directions from any given area. It follows that where identity can be established between a wide-ranging series of bowlders and rock fragments in the drift, and an equally complex succession of diverse formations *in situ* lying in a common direction from the drift which contains the identified types of rock, the conclusion that the former came from the latter is so highly probable as to amount to moral certainty. The known facts concerning the

distribution of geological formations make it incredible that a complex succession of identical formations may lie similarly in a second direction from the given locality of drift, and yet be wholly concealed.

It is not to be understood that it is possible to trace every bowlder of the drift to its exact source. Far from it. It is often impossible to tell from what formation a bowlder came. An unfossiliferous Cambrian sandstone may be indistinguishable from an unfossiliferous sandstone from various other formations. Even if it be possible to determine the formation from which a given bowlder came, it does not follow that its exact or even its approximate geographic source can be determined. It may be possible, for example, to say that a given bowlder of the drift came from the Laurentian formation. But the Laurentian formation is exposed over so great an area that it might not be possible to tell, even approximately, the direction whence the bowlder in question came, or the distance it has journeyed. In spite of these limitations, there are some types of rock, and some associations of types of rock, which are available for the determinations here suggested. Drift bowlders derived from any formation possessing distinctive characteristics, and exposed in a small area only, give very definite information concerning both the direction and the distance of their movement. Where complex associations of bowlders occur, their joint testimony may be tolerably definite on these points, even when that of each type, taken singly, fails to be so.

The fine material of the drift. The fine, earthy material of the drift is popularly called clay. If it be critically examined, it teaches significant lessons. It is found to differ in some essential respects from the mineral matter which makes up the soil and subsoil of driftless territory. The latter is composed principally of the insoluble ingredients of decomposed rock, while the former is often nothing more nor less than pulverized rock, the soluble constituents as well as the insoluble being present. If it be examined under the microscope, tiny particles of all the principal minerals which enter into the composition of any of the

bowlders of the drift of the same locality may be recognized In the clayey part of the drift, the dolomite and calcite of the limestone, the sand grains of the sandstone, the quartz, orthoclase, plagioclase, mica, hornblende, augite, olivine, magnetite, etc., and even the rarer apatite, tourmaline, zircon, garnet, etc., of the crystalline rocks, may generally be found in microscopic particles, if bowlders containing these minerals are at all plentiful. In general, the minerals which are abundantly represented in the drift bowlders of any locality, are relatively abundant in the fine earth of the drift of the same locality, while the rarer minerals of the bowlders are correspondingly rare in the accompanying clay. To this general statement there are some exceptions. The mineral particles of which the fine parts of the drift are composed often appear as fresh as if but just broken from the crystals of undecomposed rock. Where the particles are large enough so that their forms and surfaces can be distinctly made out, they are seen to be predominantly angular in shape, and to be bounded by fracture faces. They are just such particles as might result from grinding up together various sorts of rock. Furthermore, the fine earthy matter of the drift of any locality is of such mineralogical composition as to suggest that it was largely made from the grinding up of just those sorts of rock which are now represented in the large and small stones of the drift. The physical nature of the earthy matter of the drift, taken together with its mineralogical and chemical constitution, leaves no room for doubt that it is nothing more nor less than "rock flour," the product of mechanical grinding. The agencies which produced the drift must have been able to pulverize rock. No theory which does not take this into account can be acceptable.

Structure of the Drift.

Stratification. Much of the drift is distinctly stratified, and much of it is altogether devoid of stratification. Its structure is altogether independent of lithological heterogeneity, but is intimately connected with physical heterogeneity. Extreme physical heterogeneity implies absence of stratification, but absence of

extreme physical heterogeneity does not imply stratification. In many cases drift composed almost wholly of earthy material, so fine as to be popularly called clay, is wholly without stratification. In such cases there are generally some stones associated, even though they be small. Heterogeneity exists, but is not extreme. In some places, though rarely, drift composed almost wholly of sand, and therefore not remarkably heterogeneous physically, is still without stratification.

While the unstratified drift may be nearly homogeneous physically, the stratified drift never reaches extremes of heterogeneity. It may be either coarse or fine, but the very coarse and the very fine do not coexist. While there are occasional beds of bowlders the relations of which suggest stratification, the usual limit to the coarseness of stratified drift is coarse gravel. Now and then large bowlders occur in the stratified gravel, sand, or silt, but these bowlders cannot be regarded as partaking of the stratified character which affects the matrix which encloses them. They interrupt the stratification, as may often be distinctly seen. They are accidents in the stratified deposits. No part of the drift, as that term is generally understood, appears to be so fine and so homogeneous as to fail of stratification because of its fineness and homogeneity. The single apparently well-marked exception to this statement (some parts of the loess) need not be here considered.

It is sometimes the case, as fresh cuttings through the drift show, that lenses or pockets of stratified gravel or sand occur in the midst of thick beds of unstratified drift. The reverse is also sometimes true, considerable masses or chunks of unstratified drift being now and then found in the midst of extensive stratified deposits. This association, however, is much less common than the other. Where the stratified drift occurs in extensive beds, it may overlie or underlie the unstratified, or the two may alternate with each other repeatedly in vertical succession in a single section.

In some regions, the unstratified materials predominate greatly over the stratified. In other regions the reverse is true. On the

whole, stratified material is more abundant in valleys, and on low areas adjacent to high ones, than elsewhere, but there is no hard and fast topographic relation between the two types. The associations of the two phases of drift are often such as to leave no room to doubt the essential contemporaneity of their origin. The lithological likeness of their materials leaves no room to doubt that the two phases of the drift came from the same general source. From these considerations we conclude that the drift agent or agents must have been capable of producing deposits which were sometimes stratified and sometimes unstratified, and that in many places the deposition must have occurred under such circumstances as to allow of the frequent change from the one phase of deposition to the other.

Foliation of the unstratified drift. While the finer part of the bowlder-clay — the matrix in which the bowlders are set — shows no stratification, it frequently has a sort of structure which may be termed foliation. Roughly speaking, it is comparable to the foliation of gneiss, though of course without the crystallinity of the latter, and without differentiation of its mineral constituents. The foliation is always somewhat irregular, but is usually approximately horizontal, or approximately parallel with the surface. The regularity of its development is usually interrupted where it comes in contact with a bowlder. The foliation lines have a tendency to curve up over, and down beneath, the same, while at the centre of the sides of the bowlder they are rarely developed. The study of this foliation structure suggests that much of it is the result of pressure. In this case, the approximate horizontal direction of the parting planes suggests that the pressure was not far from vertical. In some cases the foliation is such as to suggest that it is the result of a shearing movement in the fine, earthy material. The position of the horizontal cleavage planes suggests that the pressure inducing the shear must have had a horizontal element.

Foliation is restricted to the unstratified portion of the drift, though even here it is by no means universal. It is rarely so distinct as to be obtrusive, and may easily escape the observation

of those whose attention has not been called to it. The true theory of the drift must be one which will allow much of the unstratified drift to have been subject to great vertical pressure, and perhaps to shearing, at the time of its formation, or since.

Shapes and Markings of the Stones in the Drift.

If the stones in the drift be carefully examined, they are found to possess significant features. If a goodly number of them be collected from the unstratified drift, it will be seen that, while their surfaces are often smooth, their forms are, on the whole, somewhat unlike those of stones rounded by rivers or by waves. While some of them are round or roundish, many others are many-sided. Their faces are often beveled. They have been worn, but the wear appears to have been effected by planing rather than by rolling. The planed sides may meet each other at any angle, though the angle along the line of junction of two faces is rarely sharp. With these planed and sub-angular bowlders and stones there are associated few or many well-rounded ones showing none of the characteristics just noted. With them also, there are occasional angular masses of rock bounded by fracture faces, which do not appear to have suffered notable wear.

If an equally large number of stones from the stratified drift be selected for examination, it will be found that rounded, water-worn forms predominate. On the other hand, specimens of the many-sided, plane-faced forms, though much less common than in the unstratified drift, are not always altogether wanting. This distinction affects large and small stones alike. It characterizes bowlders a foot in diameter, if so large stones occur in the stratified drift, and it characterizes fragments less than an inch in diameter. In case large bowlders occur in the stratified drift, they are rather more likely to have the sub-angular form than the smaller ones.

Another peculiarity goes along with the foregoing. The planed, sub-angular bowlders and rock fragments which characterize especially the unstratified drift, are often distinctly marked with one or more series of lines or scratches on one or more of their

faces. The lines of each series are parallel with one another, but the lines of separate series may cross each other at any angle. Multiple series on a single face are not rare, though less common than single series. Multiple series on multiple faces are rather infrequent, yet every student of the drift has seen them many times. Similar markings are not unknown on the well-rounded stones of the drift, though they are here much less abundant than are those of sub-angular forms.

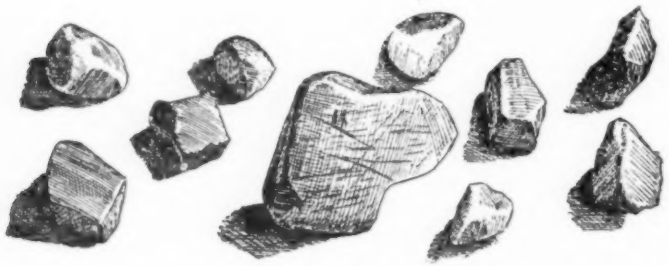

Fig. 1. Characteristic forms of small stones taken from unstratified drift. The contrast in form between these and water-worn pebbles is evident at a glance.

These markings, or *striæ*, as they are called, do not affect all the stones, or even all the sub-angular stones of the drift. If fifty per cent. of those occurring in the unstratified drift of any locality are striated, this is to be looked upon as a large proportion. On the other hand, even the unstratified drift locally contains so few striated stones that a single one is hard to find, even when good exposures are at hand. So far as concerns abundance of striæ, something depends on the relative proportions of coarse and fine materials. Much also depends on the differences in hardness between the various constituents. The striæ are much more abundant on the softer stones, such as limestone, than on the harder, such as quartzite. In much of the stratified drift, striated stones are rarely found. But in certain phases of it, they are no rarity. Where they are abundant, their forms are likely to be sub-angular, just as in the unstratified drift. Striation of surface, and sub-angularity of form, seem to go together.

The true theory of the drift must involve the action of an agent or of agents which, under normal conditions were capable of planing and beveling and striating many stones, especially the softer ones of the unstratified drift, while rounding and leaving unstriated most of those of the stratified. But the agents must have been such that under certain circumstances their activities failed, on the one hand, to leave more than a very small percentage of the stones of the unstratified drift beveled and striated, while, on the other hand, they sometimes permitted the stratification of gravels containing many sub-angular, plane-faced, striated stones, varying in size from pebbles to bowlders.

The Sources of the Drift.

Direction and distance of transportation. By tracing identifiable constituents of the drift back to their sources, it has been found that the general direction of drift transportation in the United States was from north to south. From this general direction there are many and considerable local deviations, both to the the east and west. Generally speaking, it has been found that the larger part of the drift of any locality has not been transported any great distance, though a small part of it has usually traveled far. Even at the southern margin of the drift, bowlders are sometimes found which have come from territory north of our national boundary. Those materials which have come farthest are generally of hard rock. These general statements are not without local and striking exceptions.

The forces which are responsible for the drift, therefore, must have moved, in general, from north to south, and must have been capable of local and considerable deviation both to the east and west. They must have been active over an extensive area. They must have been forces capable of gathering and carrying materials in such wise that, at the time of their deposition, the larger part had been transported but a few miles, and in such wise that the contributions of various formations to the drift of any locality are, in a rough sort of way, inversely proportional to their distance. The drift forces must have been

able also to carry large blocks of rock, and preferably hard rock, great distances, at the same time that they frequently carried a large proportion of the fine materials deposited at any given point, trivial distances only.

Size of bowlders in relation to distance from their source. Bowlders of a given type can sometimes be referred to a single source of very limited area. In such cases, it has been repeatedly noticed that the average size of the bowlders becomes less with increasing distance from their source, though individual exceptions to this rule are sometimes striking. This might be accounted for, conceivably, on either of two suppositions. Either the drift forces were not able to move the large bowlders so far as the smaller ones, or their size was reduced in the process of movement. If the latter conjecture be the correct one, the smaller bowlders, which are farther from their source, should show evidence of greater wear than the larger ones, which have not been carried so far. This might also be the case if the first supposition be the true one. For even if the drift agents could carry only the smaller bowlders considerable distances, these smaller bowlders might be worn more in their longer journey, than the larger ones, in their shorter. Between the two hypotheses the greater wear of the smaller bowlders might not therefore be decisive. But the extreme physical heterogeneity of the drift clearly indicates that the drift agents were, on the whole, very independent of the size of the materials handled. Bowlders many tons in weight were sometimes carried scores of miles. In view of this, the conclusion that the decrease in size of bowlers with increasing distance from their source is the result of wear suffered during the transit, seems the more probable. If this conclusion be correct, the drift force or forces must have been able to wear effectively the materials carried, during the process of their movement.

ROLLIN D. SALISBURY.

[To be continued.]

EDITORIALS.

THE sixth International Geological Congress is of the past. It was arranged that it should be in Zurich, but a more proper statement would be that it was in Switzerland, for the real work of the Congress was done in nearly all parts of that republic,—in the Jura at the northwest, in the great valley separating the Jura and the Alps, in the Alps, and on the Italian lakes to the south.

The officers in charge of the Congress, with admirable judgment, decided that the important matters were not acts of legislation in reference to geology, but an opportunity for the geologists of the world to gain an acquaintance with the geology of Switzerland, and the methods of work of the Swiss geologists. With these as the controlling thoughts, a series of excursions was arranged, running over a month or more. In planning these, while the geological interest of the localities was a controlling factor, care was taken that the visitors should enjoy the magnificent scenery of Switzerland. The excursions had such variety and scope that each geologist was able to find at least one before the sessions at Zurich, and one after, which covered his particular line of work, and this whether he were a palæontologist, a structural geologist, a glacialist or a petrographer. The excursions were further divided into two classes: the first provided for those who did not care for, or were not able to endure physical hardship, and therefore were largely by carriage, steamboat, and railway; the second class, largely on foot, provided for those who were able to take long walks and endure severe climbing. The rendezvous for the excursions before the sessions were at various places in Switzerland. They were all well arranged so as to converge naturally at Zurich. After the Congress another set of excursions diverged from Zurich and converged at Lugano. Those before the Congress were in the Jura, those after in the Alps. All who went on

one journey before and one after the Congress were able to obtain a good general idea of these two grand mountain systems, and the great valley separating them.

In order that the excursions should have the greatest success, there were published in advance a new geological map of Switzerland by Heim & Schmidt, a number of special memoirs by various geologists, and an excellent official guidebook, an octavo volume of over 300 pages, with numerous figures, maps, and sections. This book has a large number of parts, each one pertaining to a particular excursion. In most cases each part has a general statement of the geology of the district traversed and a detailed account of the phenomena to be seen on each day of the journey.

If one may judge by the two excursions which the writer was able to attend, the conductors were masters of the geology of the area covered, and eager to make the expeditions both pleasant and profitable to all participating. Not only is this true, but the citizens of Switzerland seemed to regard the Congress as a national affair, and wherever the parties went, they were treated with the greatest consideration and entertained with lavish hospitality.

At the sessions at Zurich there was no attempt whatever to legislate on any scientific question of geology. The meeting differed chiefly from other gatherings of geologists in that it was international, and was therefore attended by an unusually large number of eminent men. At the general sessions exceptionally valuable papers were presented by some of the more prominent geologists. Papers of a more special nature were read before the several sections of General Geology, Stratigraphy and Palæontology, Mineralogy and Petrography, and Applied Geology. One could therefore listen to the papers which were of particular interest to him, without being under the necessity of hearing others.

The excursions and sessions afforded an excellent opportunity for mutual acquaintance and interchange of ideas. It will doubtless be the experience of each geologist who attended the Congress, as he reads the works of men with whom he has become acquainted, that they will bring to him the image of the person

who created the works. The friendships formed and the consequent sympathy with one another cannot fail to be a stimulus to mutual kindly criticism and helpful suggestion. The widening acquaintance in the past few years of many of the geologists of the world is without doubt one of the chief causes of the decline of unpleasant controversy. This bringing men together from all lands, and the formation of personal relations between them may perhaps be considered one of the most important functions of the International Congress. In this particular, if this be true, the last session was unsurpassed in importance by any previous one.

The only feeling of discontent which one brought away was grounded on the human limitation of indivisibility, for many interesting things were occurring at the same time. One wished not only to accompany one excursion before and another after the sessions, but two or more, and many found it very difficult to decide between them. The same may be said of the sessions. But this criticism is one which our brothers in Switzerland will doubtless take without hostility. The writer, and I have no doubt all other geologists foreign to Switzerland who came only with a desire for the advancement of geology, went away with a warm feeling of gratitude toward the Swiss geologists, who labored so long and faithfully to make the Congress what it was,—a high success.

C. R. V. H.

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THE explorer that enters a field whose sensational phases excite extreme popular interest must often pay the penalty of misinterpretation. His chief motive is easily supposed to spring from the sources of chief popular concern. It is not easy for the masses to suppose that he is stimulated by any higher interest than that which appeals most strongly to them. The discomfort of this is offset, in a certain way, by the popular tribute which is accorded him solely because his endeavor is misconstrued. His true purpose would be received with indifference. It is only when those whose interest takes a higher form share in the popular interpretation, without sharing in the popular interest and applause, that the penalty becomes a proper source of

concern. When, for instance, in lieu of an effort to prove the insularity of Greenland, a race for the "fartherest north" appears as the prime motive of an expedition, the masses are all agog, but scientists become indifferent. An adventurous rush for the pole, and an effort to determine the rotundity of the ice cap, awaken diametrically opposite sentiments among the two classes. The interest of the one rises as that of the other falls.

As motives in all endeavors are doubtless more or less mixed, it will be fortunate if each class can find in every laudable enterprise a purpose congenial to its own point of view, provided always the hazard of the endeavor does not bar it out from legitimate undertakings. Beyond question, popular interest in Arctic exploration centres about the "fartherest north" and the attainment of the pole, and is grounded in the human factors of competitive courage, strength, sagacity, and luck; while scientific interest is chiefly centred upon the physical and biological features of the region considered as elements of our great environment, to know every part of which is prerequisite to knowing any part well. In so far, therefore, as proper endeavor falls within the limits of legitimate hazard, the conjunction of popular with scientific interest is a helpful source of support and promotion, and, in view of this, the true explorer may be challenged to ake courageously the good and ill of personal interpretation until time shall bring its due, and presumably its true, adjudication.

The scientific factors in the work of Lieutenant Peary are worthy of note, quite apart from any admiration which his courage and perseverance may awaken. It should be more generally known that, during those portions of the season when his party have not been engaged in his great endeavor to complete the outlining of the northern and eastern coasts of Greenland and of the archipelago which is presumed to constitute its extension northward, they have been employed in the mapping of the western coast on a more detailed and accurate basis. This has not been confined to the portion near the headquarters of the party on Inglefield Gulf. Many additions have been made to existing knowledge of the coast all the way from Melville Bay

to Cape Alexander, and even beyond. Inglefield Gulf and its dependencies, which on our charts are little more than a caricature, have been outlined with considerable accuracy, the leading points about Bowdoin Bay being fixed by triangulation. Mr. Astrup has made a new map of Melville Bay, which, notwithstanding the prominent and grewsome part it has played in northern navigation, is laid down on the charts with great inaccuracy. The outlines of the inland ice, and the glacial tongues which protrude from it, have been delineated with much greater approach to accuracy than heretofore. Other geological features have received attention. As elsewhere indicated, in addition to the geographical features of the glaciers, some of their physical characteristics, including their rates of movement, have been studied.

The meteorological observations, in the hands of Mr. E. B. Baldwin, formerly in the United States Weather Service, have been commendably complete in plan and successful in execution. In kind and grade they have been essentially the same as those required at our weather stations of the first order. The barograph and the thermograph were not only successfully manipulated at headquarters, but were kept in operation upon a sledge during the journey on the inland ice in the stormy months of March and April, as was also the anemometer. *Continuous* records of the temperature and of the atmospheric pressure and movements were thus secured. This is, we believe, quite beyond precedent. Perhaps nothing can better show that Lieutenant Peary's expedition was something more than an adventurous rush for the "fartherest north," or even for mere extent of coastal exploration, than this successful attempt to carry delicate instruments of continuous and exact record on a perilous trip, where every pound of burden and every expenditure of effort were matters of moment to the outcome.

This is not the place for an extended sketch of the scientific work of the expedition, but the citation of these items may aid in giving to genuine scientific interest and appreciation a tangible basis, quite apart from the humanistic phases of the enterprise that most attract the general attention. T. C. C.

Reviews.

The Great Ice Age. By Professor James Geikie. Third edition. London: Edward Stanford, 1894, pp. xxviii + 850. xvii plates.

The progress of glacial geology has been so great during the last few years that a new edition of this classic work is most welcome. Much the larger part of the volume has been rewritten. Even those parts which are only revised are so modified that they read as if now written for the first time. Apart from the alterations which the studies of recent years have made necessary, the general scope of the volume is somewhat changed. In the present edition, the glacial phenomena of the continent of Europe have received much fuller and much more systematic treatment than in the preceding. The glacial phenomena of Asia, Africa, Australia and South America also come in for their share of attention. The chapters which deal with the glacial phenomena of North America (52 pages) were contributed by Professor Chamberlin, and suggest much that is new in the way of classification and correlation. Another important change is the transfer of the discussion of the causes of the glacial period to the end of the volume. This arrangement seems to make this chapter much less than heretofore an organic part of the volume, and it is distinctly pointed out that the general facts and relations set forth in the rest of the volume are not dependent on any particular theory of glacial climate. Many of the minor changes of the volume are significant, and not the least point of significance is the fact that they are very generally brought into harmony with the results of recent research in our own country.

By way of illustration it may be mentioned that kames and åsar are now sharply distinguished from each other, and that the discussion concerning their origin is somewhat changed. It is interesting to note that Professor Geikie believes the åsar to be, for the most part, the products of subglacial, not of superglacial streams. In connection with kames some interesting facts concerning their distribution and relations are indicated. In Scotland they are said to be especially abundant "oppo-

site the mouths of our larger valleys." Quoting Mr. Jamieson, Professor Geikie points out that kames are often grouped in belts which "lie across valleys in long sinuous lines, forming curves or segments of a circle, the concavity of which is presented to the head of the valley, and their convexity toward the sea or downward end, as in terminal moraines." Outside these belts and groups of kames, there are frequently found wide flats of gravel and sand, sustaining the same relation to the kame-belts that similar deposits sustain to moraines, and, more rarely, to belts of kames in our own country. Professor Geikie does not fail to note the close relationship between certain aggregations of kames and terminal moraines. It was just this moraine-like habit of certain kame belts, moraine-like both in themselves and in their relations, which led the writer to propose for them the name *kame-moraines*.[1]

Apropos of the question which has been raised, on this side of the water, as to the reality of the existence of rock basins produced by glacier erosion, it may be noted that Professor Geikie asserts that the "largest and most important lakes of Scotland" as well as a "vast number of mountain tarns" lie in rock basins. There is no hesitation in ascribing these rock basins to the work of glacier ice.

Important as many of the minor changes in the new edition are, the chiefest interest is likely to centre in the discussion concerning the succession of glacial epochs. In Scotland Professor Geikie finds what he regards as evidence of five glacial epochs. In England the Weybourn and Chillesford crags are believed to represent the deposits of a still earlier epoch when the climate was arctic in Britain, and when considerable glaciers were in existence, though the crag deposits themselves are not looked upon as the direct product of ice. These crag deposits, together with the overlying Cromer forest beds, are referred to the Pliocene. According to this interpretation, the beginning of the glacial period is not coincident with the beginning of the Pleistocene.

Instructive maps are given, showing the extent to which the ice covered Great Britain and Ireland, and the continent as well, in the second, third, and fourth glacial epochs. During the second epoch, Ireland, Scotland, and Wales were completely covered by ice, and glaciation extended essentially to the valley of the Thames. On the continent the ice is represented as having extended so far south as to cover

[1] Annual Report of the State Geologist of New Jersey, 1892, page 93.

all of Holland and part of Belgium. In Germany it extended to the Erz and Carpathian Mountains. It reached its southernmost extension in the valley of the Dneiper, somewhat below latitude 50°. A further point of interest is the representation of an independent ice sheet of considerable extent in northeastern Russia and the adjacent parts of Asia, about the Timan and Ural Mountains. The ice sheet which centred here is mapped as extending westward until it came in contact with the ice sheet which spread eastward from Scandinavia. This subordinate ice sheet had an area about as great as that of France. According to the map, the edge of the ice during this epoch was markedly lobate, especially to the eastward. Expression is also given to the idea that some of the mountain ridges well within the area of the *mer de glace* exerted, even at the time of maximum glaciation, a considerable influence on the direction of ice movement. The mountains of Great Britain, of Ireland, and of Eastern Scandinavia are represented as having never been so deeply covered with ice but that they continued to exert an influence upon the direction of its movement. They served as local centres of glaciation while the ice sheet was developing, and as such would seem never to have altogether lost their identity.

During the next glacial epoch (the third) ice again covered all of Scotland, but failed to override the southern extremity of Ireland. It left a considerable part of Wales uncovered, and encroached upon the borders of England only at the north, northwest, and northeast. On the continent, the ice failed to reach its earlier limit. Hamburg, Berlin, and Warsaw lie near the limit of its advance, and there was no independent ice sheet in the region of the Urals. The Scandinavian and British ice sheets were again confluent. During the fourth epoch, glacier-ice in Britain was largely confined to the mountain valleys of Scotland, though the valley glaciers sometimes came down so as to coalesce on the low lands, making somewhat extensive "district" or piedmont glaciers. On the continent, the ice covered the eastern half of Denmark, and reached southward to the Baltic ridge. It failed to cover all the southern part of Sweden, and did not encroach far upon Russian soil. The British and Scandinavian ice sheets were not confluent. During the fifth and sixth epochs, the development of ice was still more restricted, the glaciers of the last being less extensive than those of the fifth.

What is the basis on which the subdivision of the glacial period is

based? There would seem to be no question as to the distinctness of the Weybourn crag from the oldest glacial formations of the British Isles. The only question would seem to be concerning the glacial character of the Weybourn crag epoch. In favor of this view Professor Geikie seems to make a strong case. Between the drift of the second and third glacial epochs, the "lower" and "upper" bowlder clays of England, there seems to be a well marked interglacial horizon. This horizon represents an interval during which the land surface of Britain was considerably elevated. During the time of elevation the climate changed from arctic to temperate, and the land surface became well clothed with vegetation, and was occupied by man and Pleistocene mammalia. Following this condition of elevation, there was submergence of the land to an undetermined extent. During the submergence the climate changed from cold-temperate to arctic. The increase in the severity of climate accompanying the submergence resulted in a second *mer de glace*. Thus a very considerable period of time, accompanied by a very considerable amelioration of climate, and by very considerable changes of level, separated the lower drift of Britain from the upper.

The evidence on the basis of which the third epoch represented in Scotland (the fourth of the full series) is separated from the preceding, is drawn from several sources. (1) The mountain valley lake basins are believed to represent the work of advancing ice, not the work of the receding ice (valley glaciers) of the third epoch. (2) The bowlder clay in the mountain valleys possesses a topography which is fresher (less eroded) than that of the bowlder clay of the surrounding country. (3) Above the valley moraines which are thought to mark the termini of the glaciers of this epoch, there is an absence of till in the bottoms of the valleys, and on their lower slopes. Higher up the slopes bowlder clay is present, as also in the same valleys below the moraines. The absence of bowlder clay in the situations specified is attributed to the erosive work of the mountain glaciers of the third (Scotland) epoch. (4) The moutonnées, striæ, etc., in the areas thought to have been covered by the local glaciers of the third epoch are fresher than the corresponding features elsewhere. (5) The coincidence of direction of ice movement with the courses of the valleys in the third epoch is striking, while during the preceding epoch the direction of ice movement was independent of topography. (6) It is thought that after the last great ice sheet (that of the third ice epoch) withdrew from Scotland, there

were considerable changes of level, before the ice of the next epoch reached its greatest development.

The evidence brought forward along these lines in support of the separation of the epoch of the "district" glaciers of Scotland from the epoch of the preceding *mer de glace* is such as to make it clear that the former was in some measure distinct from the latter. The ice of the so-called fourth epoch would seem to mark a distinct stage in glacial history, a stage when the ice was more active than for a time preceding. But the evidence is not such as to make it clear that the epoch of "district" glaciers was so far separated from the last *mer de glace* of Scotland as to entitle it to the rank of a separate epoch, as that term is used in America. If local glaciers of the dissolving ice sheet tarried long in the mountain valleys, their persistence would seem to explain some of the phenomena cited as evidence of the separation of the epochs. A temporary and relatively slight re-advance of such glaciers during the general dissolution of the ice sheet might bring them again into vigorous action. Such recrudescence would at least help to explain such phenomena as call for advancing ice. The coincidence of the direction of striæ in the mountain valleys with the slopes of the surface, and the independence of striæ with reference to slopes elsewhere, does not seem to the writer strong evidence of an independent ice epoch during which the ice was largely confined to the valleys. It is believed that existing striæ were very often, if not very generally, made by the later phases of ice movement in the regions where they occur. It seems rational to believe that while Scotland was covered with ice to great depths, the movement of the same was largely independent of topography; but that later, when the ice was undergoing dissolution, when the highlands had become bare, and when the valleys were still occupied by ice, its motion was in correspondence with the local slopes. Such striæ as were developed at that time would necessarily be in harmony with the direction of the valleys. It is believed that a re-advance might take place sufficient in vigor to explain the phenomena cited from Scotland, without being of sufficient extent, or of sufficient importance from other points of view, to be regarded as a distinct glacial epoch. If, on the strength of the evidence presented, we are not altogether convinced that the third glacial epoch represented in Scotland (the fourth of the full series) was sufficiently distinct from its predecessor to be ranked as a distinct epoch, as we have been accustomed to use that term, it does not follow that new evidence may not yet

lead to this conclusion. If the fourth epoch of Professor Geikie be no more than an episode, as terms are used in America, the recognition of its proper measure of distinctness is still important. An episode may ultimately come to possess a significance scarcely less than that of an epoch. Even if the "district" glaciers represented but a very moderate re-advance of the ice, this re-advance is worthy of differentiation since it helps to emphasize the general fact of the complexity of the glacial period as a whole.

When we come to the separation of the fifth from the fourth glacial epoch, and of the sixth from the fifth, it must be confessed that the evidence presented is very far from convincing, if the word epoch is to retain the meaning which has been attached to it in this country. From the written page it does not appear that the so-called fifth and sixth glacial epochs of Scotland necessarily amount to more than considerable recrudescences of glaciers which were previously retreating. But even if these recrudescences be of minor extent only, they should be recognized for what they are. If they be not separate epochs, in our sense of the term, there can be no doubt that they represent more or less distinct advances of the ice, and their separate recognition helps to emphasize what seems to be the fact in America as well as in Europe, viz., that the glacial period was long and complex. To this conclusion detailed work on both continents seems to be surely leading.

The drift of Southern England, "rubble drift," "head," etc., is ascribed to torrents connected in time with the ice epoch. The material, if we understand Professor Geikie rightly, is not for the most part material that was worked over by the ice, but rather the product of rock disintegration in cold climates. It is believed that the frozen surface outside the ice prevented the penetration of the rain water. Under these conditions, precipitation and drainage might give rise, especially in the warmer seasons, to considerable floods. Such waters, it is believed, bore the rubble from its native place and spread it upon the plains to the south. If this interpretation be correct, it may have an important bearing on gravel deposits outside the glacial drift in other countries.

On the continent, "upper" and "lower" series of drift deposits are recognized on all hands. There are numerous beds which have been more or less generally classed as interglacial. They are found at intervals over a stretch of country extending from the North Sea to Moscow. Many of the continental geologists have been in the habit of putting them together, and of regarding them as the great division plane between the "upper" and "lower" tills. Independently of the inter-

glacial beds, an "upper" till is sometimes seen to be distinctly unconformable on a "lower," the relations being such as to indicate that the lower was exposed for considerable periods, and subject to extensive erosion, before the upper was deposited on it. This relationship does not necessarily indicate great recession of the ice between the times of deposition of two bodies of till. So far as the physical relations are concerned, the upper body of till might be the work of an advancing ice sheet which had previously retreated but a short distance, but which remained long in retreat.

It is surely most significant that the same general conclusions concerning the multiplicity of ice epochs are reached, whatever part of the continent be examined, provided it be within the glaciated area. Thus in Northern Norway, after an epoch of glaciation there appears to have been an epoch of submergence until the sea stood 63 meters higher than now. Then the land rose so that the sea stood about 35 meters higher than now. Then followed another epoch of glaciation. Between the deposits of these glaciations there are marine beds containing fossils. In Southern Sweden there are non-glacial fossil-bearing beds overlain and underlain by ice deposits. In Schleswig and the Danish Islands there are similar beds in similar relations. Of the eighteen species found in these beds, eleven have a southern range, four have a wide range north and south, while three species only are distinctly northern. Again in Eastern Holstein, and on the islands of Rügen and Bornholm, there are similar beds, similarly situated.

The interglacial beds are best developed in Eastern and Western Prussia, where they are of greater thickness, and occupy greater areas than elsewhere. They include sand, peat, etc. Some of them are marine, while some are of fresh-water origin. They have yielded many fossils. The general facies of their molluscan faunas, both marine and fresh water, denotes a temperate climate. All the marine molluscs are North Sea forms, and still live in the Kattegat. Most of them are now living in the western Baltic. The testimony of the fossil land mammals confirms that of the molluscan faunas as to the temperate climate of the continent between successive glaciations.

Considered as a whole, the character of the "interglacial" fossil beds of Northern Europe is such as to indicate that if they belong to one epoch, that epoch must have been one of considerable length and complexity. Interglacial peat beds in Holstein sometimes alternate with sand, and contain floras which denote considerable changes of climate,

from cold to temperate and back again to cold. The mammalian remains likewise indicate fluctuations of climate. In Central Russia there are fossil beds overlying the drift of the most extensive ice sheet. These fossil beds are not buried by till, since they are beyond the limit of the later advance of the ice, but they are clearly neither post- nor pre-glacial. They are thought to represent a climate more humid and more mild than that which now exists in the same region.

Evidence for the existence of multiple ice epochs is not confined to the fossil beds, strong as their testimony is. In Germany there is an "upper" bowlder clay different in physical and lithological constitution from the "lower." This implies a difference in direction of movement of the ice which formed the two beds of till. Thus in Western Germany, the "lower" till was deposited by ice moving from north to south, while the "upper" till was deposited by ice moving from north of east to south of west. This two-fold division of the bowlder clay exists south of the region of the great Baltic ridge, though the southern limit of the "upper" till south of this ridge seems not to have been accurately determined.

As in Britain, so on the continent, Professor Geikie finds evidence that the ice-sheet which reached farthest south, and which deposited the "lower" till of Western Germany, is not the oldest ice-sheet which affected Northern Europe. In Southern Sweden there is a till or ground moraine older than that produced by the most extensive ice-sheet. This oldest bed of drift, so it is affirmed, was deposited by ice moving from the southeast to the northwest. The overlying drift is the product of ice which moved from north-northeast to south-southwest, or nearly at rignt angles to the direction of the first movement. No interglacial beds are found here, but the diversity of movement is so great that, taken in connection with the extraordinary direction of the first, its significance cannot be trifling. It is to be noted that the foregoing interpretation does not involve three periods of drift deposition in Southern Sweden. The "lowest" ground moraine is referred to the first epoch (the time equivalent of the Weybourn crag), while the "upper" must be made to include the deposits of the second and third, if deposits of both exist. Some corroborative evidence of a great "Baltic" glacier, which antedated the most extensive *mer de glace* of the continent and of Britain, is thought to be found in certain fossil beds of Central Germany, though for their own particular region these fossil beds are thought to be pre-glacial. The "lower" till of Central Ger-

many is correlated with the "lower" till of Britain (second glacial, but first Pleistocene glacial epoch). The "upper" till of Central Germany (south of the Baltic ridge) is separated from the "lower" by beds containing the remains of a temperate fauna and flora. For the distinctness of the epochs of these two sheets of drift, the evidence is certainly strong. The "upper" till is correlated with the drift of the second Pleistocene *mer de glace* of Britain.

The great Baltic ridge of North Germany is regarded as a huge terminal moraine, on the outer part of which are the *End-moräne* or *Geschiebewälle* of the Germans. This moraine is looked upon as the southern margin of a sheet of drift which overlies the "upper" till of Central Germany. Some of the fossil beds of North Germany are believed to lie between this third sheet of drift and the second, the second being the equivalent of the "upper" till of the region south of the Baltic ridge.

The "lower" till of Schleswig within the Baltic ridge, is thought to correspond with the "upper" till of Middle and Western Germany. This implies that the direction of movement during the time of the great Baltic glacier, was notably different from that during the production of the "upper" till of Middle Germany. Furthermore, the so-called "lower" till of Schleswig is known to be underlain by a still lower till separated from it by fossil beds indicating a temperate climate. It is therefore concluded that the till of Schleswig is referable to three distinct epochs. The basis for the reference of the drift sheet limited on the south by the Baltic ridge to a separate epoch — the fourth — is threefold: (1) The fossil beds between it and the next lower drift-sheet; (2) the change of level which these fossil beds imply; and (3) the differences in direction of movement. The drift which is limited by the Baltic ridge in Germany is correlated with the epoch of the "district" glaciers in Scotland.

Evidence for a fifth glacial epoch, that is, an epoch later than that of the great Baltic glacier, has not heretofore been recognized in Scandinavia. The mountain valley moraines of that peninsula have been regarded as moraines of recession. From this conclusion Professor Geikie is inclined to dissent. He is disposed to think that these moraines may represent a minor ice epoch or ice epochs, corresponding with the latest epochs of Scotland.

It is interesting to note, though too much weight must not be attached to the analogy, that the outermost border of the drift in

Europe, as in America, is not characterized by terminal moraines; that the limit of the drift deposited during the second advance of the ice in Europe, as in America, is not commonly marked by well-defined moraines, though moraines are not altogether wanting; that the great body of loess in Europe, as in America, seems to be connected with the ice advance which succeeded the greatest; and that the ice during the next succeeding advance (the second after the greatest), both in Europe and America, developed the great terminal moraines, and that these terminal moraines are bordered on the outside by plains and valley trains of sand and gravel, denoting more vigorous drainage than during the earlier stages of the ice.

A chapter is devoted to the glaciers of Middle Europe. Nearly all the mountains of this part of Europe had their glaciers during one or more of the glacial epochs. In some of these regions, as in the Vosges Mountains of Alsace, there is more or less evidence of separate epochs with inter-current non-glacial conditions.

In Switzerland details concerning the glacial formations have been worked out in great detail by several geologists, among them Messrs. Penck, Brückner, Böhm, and Du Pasquier. Much of the work in Switzerland has been done independently, but the conclusions reached appear to be nearly the same in whatever part of the Alpine country the areas investigated lie. Three thoroughly distinct series of glacial deposits are recognized, separated by interglacial beds representing genial climatic conditions. The intervals between the successive glaciations were long, perhaps longer than the time since the last. This evidence is not confined entirely to the regions which were actually covered by the ice. It is also found in territory which ice did not cover. The evidence outside the areas actually glaciated is drawn from three series of gravel deposits. The oldest series of gravels, which Professor Geikie calls the "plateau" gravels, were deposited during the first recognized epoch of glaciation in the Alps. After the deposition of these gravels there was a long period of erosion. Streams cut deep and broad valleys through these gravels, and into the rock upon which they rest. During this erosion interval the Inn, for example, deepened its valley several hundred feet.

In the valleys thus formed, a later deposit of glacier gravel was made. This gravel constitutes the so-called "high terraces." There is direct evidence that this gravel was connected in time and origin with the second glacial epoch of the Alpine region. Subsequent to the deposi-

tion of this second series of gravels, there was a long period of erosion and weathering, during which deep valleys were cut in the high terrace gravels. This period of erosion corresponds with the second interglacial epoch of the region. Later, a third series of glacial gravels was deposited in the valleys cut out of the second series. This third series may be traced into direct connection with the terminal moraines in the mountain valleys. The foregoing sequence was first established by Penck for Upper Bavaria, but it has been found to hold for all the Alpine *Vorland* between the Rhine and the Traun. By Professor Geikie these three glacial epochs of Switzerland are believed to correspond to the first three glacial epochs of Northern Europe.

The argument for the tripartite division of the glacial deposits of Switzerland as stated by Professor Geikie, seems strong. The evidence has been gathered with great care by those on whose conclusions we have learned to rely. Until it is decided how far the ice must have retreated, relative to earlier and later advances, and how long it must have stayed in retreat, in order that a re-advance shall constitute a new ice epoch, there is of course chance for discussion as to whether these separate series of glacial deposits represent distinct glacial epochs. But from Professor Geikie's exposition, there can hardly be a doubt that the three subdivisions of the Alpine drift are thoroughly distinct, distinct enough to make their reference to separate epochs the most natural method of classifying them.

Later than the three glacial epochs, as determined by Penck and his associates, there are said to be two later sets of moraines in Switzerland. To these Professor Penck assigns a "post-glacial" age. Geikie thinks they may belong to the fourth and fifth epochs, according to his general classification for the whole of Europe. This would make five glacial epochs in Switzerland, according to Geikie, two of which are "post-glacial," according to Penck.

Evidence of the same general import is likewise found in the Auvergne. It will thus be seen that the evidence for the existence of multiple glacial epochs is not confined to one area, or even to a few closely associated areas. The evidence is drawn from widely separated sources, and is found in all regions which were extensively affected by glaciation.

Concerning the general question of the division of the glacial period into epochs, it may be said that too much reliance is not to be placed on specific bits of evidence, or on specific lines of evidence.

Specific bits of evidence, or even whole lines of evidence, which are cited in support of separate epochs, might be interpreted in some other way. But in dealing with such questions we have always to remember that several lines of evidence, no one of which is absolutely conclusive, may together be so strong as to carry conviction. The question is not whether this or that bit or line of evidence *might be* explained in some other way than by the theory of distinct glacial epochs, but whether, as a matter of fact, the aggregate of evidence compels the adoption of this theory. The question is not *what might have been*, but *what was*.

According to Professor Geikie the sequence of events during the prolonged glacial period is as follows: (1) A glacial epoch, preceded by a period of increasing cold. At this time ice filled the basin of the Baltic. The Alpine lands were swathed in snow and ice, and great glaciers came out from the mountains, making moraines on the low ground at their bases. The mountain regions of Britain were probably ice-clad, though of this there is no direct evidence. In France there were glaciers from the volcanic cones of Auvergne and Cantal, which descended so as to deploy upon the plateaus. (2) Then followed the first interglacial epoch. The southern part of the North Sea became land, and a temperate flora, comparable to that of England today, covered corresponding latitudes. A luxuriant deciduous flora occupied the valleys of the Alps, and flourished at heights which it no longer reaches. (3) The first interglacial epoch was succeeded by a second glacial epoch. During this time the northern *mer de glace* reached its greatest extent. At the same time, the Alpine glaciers reached their greatest extension, while in the other mountains of Europe snow fields and glaciers came into existence. (4) The dissolution of this ice sheet was followed by a second interglacial epoch. The climate of Northern and Central Europe again became temperate, a temperate flora and fauna finally replacing the arctic forms which first tenanted the land after the ice disappeared. The plants which occupied Germany and the central plains of Russia indicate a less extreme climate than is now experienced in these regions. Later, the climate became more rigorous. The amount of erosion accomplished during this second interglacial interval was such as to testify to its great duration. (5) A less extensive, but still great ice sheet overwhelmed a large part of the British Islands, and spread itself widely upon the continent. As in the preceding epoch the Scandinavian and British

ice sheets were confluent. From the Alps great glaciers descended to the lowlands. (6) Eventually the ice of the third epoch disappeared and temperate conditions succeeded. Of this change the best evidence is furnished by the younger interglacial beds of the Baltic coast-lands. (7) The fourth glacial epoch succeeded the third interglacial. During this epoch the Lowlands of Scotland were submerged to a depth of 100 feet. The Highlands of Scotland had their glaciers, which in places reached the sea. The Alpine glaciers flowed for long distances down the great valleys, but fell far short of the dimensions reached by those of the earlier epochs. From Scandinavia, the ice moved south to the Baltic ridge in Germany. (8) Following the fourth glacial epoch there was a fourth interglacial epoch, when deciduous trees spread far north into regions where such trees no longer flourish. The Baltic was converted into a great lake. Submergence followed, and the Baltic became an arm of the sea, with a fauna indicative of a warmer climate than the present. (9) During the fifth glacial epoch there were local valley glaciers in the British Isles, the position of which shows that the snow line in Scotland had an average height of 2500 feet. During this epoch Scotland was submerged to an extent of about fifty feet. In the Alps, the fifth glacial epoch is marked by moraines of the second so-called "post-glacial" stage. (10) The fifth interglacial epoch was marked by the re-emergence of the land and the retreat of the valley glaciers. Britain's area became wider than at present, but it is not known that connection was made with the continent. (11) During the sixth glacial epoch Scotland was submerged twenty or thirty feet more than at present. The snow line then stood at an elevation of something like 3500 feet in Scotland, and a few small glaciers existed in the lofty mountains. It is to be noted throughout, that elevation and amelioration of climate go together, while colder conditions accompany subsidence.

Concerning the origin of the loess Professor Geikie takes no uncertain ground. He believes that it was primarily an aqueous deposit, made during the closing stages of more than one glacial epoch, but that the principal body of it was connected with the closing stages of the third epoch. Subsequent to its first deposition, it is held that the wind shifted it from the position in which it was left by the water, on a somewhat extensive scale. The fossils of the loess seem to indicate that an arctic fauna was succeeded by a sub-arctic, and this in turn by a temperate one.

In his chapter on extra-European countries, our author recounts evidence to the effect that there were extensive glaciers in most of the mountain ranges of Asia during the glacial period. At this time glaciers are believed to have been much more extensive than now, in regions where they now exist, and to have existed in many places where they are not now found. The glacial deposits of Asia have been little studied, and have not thus far yielded evidence of recurrent epochs. In Africa there is evidence that there were somewhat extensive glaciers in the Atlas Mountains, where there are said to be large moraines at an elevation of not more than 6000 feet. There is evidence, too, that glaciers descended much lower than at present from some of the mountains near the equator. Thus about Mt. Kenia (18,370 feet) glaciers have at some time descended between 5000 and 6000 feet lower than at the present time. In South Africa, likewise, there are traces of glaciers in the mountains at elevations ranging from 1000 to 5000 feet. In the Australian Alps, glaciers are found to have descended to a level little more than 3000 feet above the sea. There is evidence also of glaciation at points in South Australia. Within this province the effects of ice action are observable down to within forty feet of the sea level about St. Vincent Gulf, latitude 35° south. There are also evidences of former glaciers in Tasmania, and the ice in New Zealand is known to have been much more extensive at some earlier time than now. Kerguelen Island, it is believed, has at some time been completely smothered by ice. In South America, too, glaciers were formerly much more extensive than now.

Professor Geikie makes no specific statement looking to the time correlation of the glacial conditions in these various countries with those of Europe and North America, but the implication, perhaps unintentional, is that they fall within the limit of the glacial period of those countries. Until the cause of the glacial period is known, it would seem to be unfortunate to assume that the glaciation of different continents was synchronous.

The chapters devoted to the drift of North America are more than a summary of the drift phenomena of our continent. They are written from the standpoint of Pleistocene history and embody new suggestions on many points.

Professor Chamberlin calls attention to the fact that the known history of glaciation practically begins with the time when the ice reached its outermost limit. The earlier glacial history is largely lost, and that

which is not altogether lost, is greatly obscured. A distinct innovation is suggested in the chronological classification of the drift. Instead of referring to a given drift deposit as belonging to the first, second, or third glacial epoch or episode, it is proposed to designate the deposits made during the more distinctly marked stages of the glacial period, by the names of type localities. Thus it is proposed to apply the name *Kansan* to the deposits made by the most extensive sheet of ice. This formation is now uncovered only along the southern border of the drift. As now exposed, it finds extensive development in Kansas, Missouri, Illinois, Iowa, Nebraska, and Dakota, and lesser development in several other states. In general, this formation is thin at its outer edge, its terminus not being marked by morainic accumulations. It has suffered much erosion. In many regions, remnants only have escaped destruction at the hands of erosive agencies. The rock surface underlying the exposed part of this formation was in general little modified by the ice.

The Kansan formation is overlapped by another sheet of drift, the *East Iowan*, which encroached upon it from the north, leaving only its southern margin exposed. Between the two formations there is a widespread body of soil, which is in many places thick. It was probably as well developed as the soils of the present surface. It is known to extend fully fifty miles back from the outer border of the East Iowan formation. The plant remains which this soil contains have not been studied in great detail, but they are such as to indicate a temperate climate. The interval of deglaciation therefore was important. This interval of deglaciation is called the post-Kansan interval. Some estimate of its length is also based on the amount of erosion which the Kansan formation has suffered, compared with that which has affected the next succeeding formation.

Like the Kansan, the East Iowan formation was once widespread, but as a rule only that part of it which was not covered by later drift can now be certainly differentiated. Like its predecessor the East Iowan formation is not generally bordered by distinct terminal moraines. With the East Iowan formation, the main body of the loess seems to have been connected in time of origin.

Following the East Iowan formation, it would appear that there was an interval of deglaciation sufficiently long "to permit a notable change in the configuration and conditions of the land — the development of capacious valleys; the general carving of the surface into an erosion

topography; the production of vegetal beds and soils, and the deep penetration of weathering."

Following this period of deglaciation, the ice again advanced, making, and finally leaving, the body of drift which it is proposed to designate the *East Wisconsin* formation. As now exposed this formation is much more extensive than either of the preceding, though it is less extensive than either of the others were before they were buried and disturbed or destroyed by later incursions of the ice. It is characteristic of the East Wisconsin formation that it is bordered by great moraine loops. It is also characteristic of this formation that extensive gravel plains, in distinction from silt and loess plains, border its moraines on the outside. It is in connection with this formation that drumlins, kames, and osar are best developed. The East Wisconsin formation is by no means simple. During its development there were repeated oscillations of the ice edge. Some of them may have been considerable, but they are not believed to mark more than minor stages in the history of the glacial period.

At several closely associated points in the vicinity of Toronto there are fossil beds of stratified drift between beds of till. These fossil beds have yielded a rich flora and fauna, which have recently been studied by Messrs. Coleman, Townsend, and others. The character of the fossils is unequivocal. They indicate a climate milder than that of the present time in the same region. The molluscan fauna would be appropriate to Southern Illinois, the flora to Southern Ohio. Unfortunately, the position of the fossil bed in the great drift series is not certainly known. It is hardly probable that it belongs between the Kansan and the East Iowan formations. It is more probable that it lies between the East Iowan and the East Wisconsin formations. On the other hand, it may lie between the East Wisconsin formation, and the deposits of a later ice epoch which, within the United States, has not been differentiated from the preceding. If the fossil bed occupies the position last mentioned, there would be reason for separating the drift series into four principal formations, rather than three.

Professor Chamberlin is very conservative with reference to the chronological importance of the several subdivisions which he proposes. He does not assert that the three main subdivisions for which he proposes names, are of equal importance. It is left an open question which of the two deglaciation intervals between these formations is the more important. It is left an open question, so far as

affirmation is concerned, whether either one or both of these intervals is of sufficient importance to constitute the succeeding ice advance a separate glacial epoch. It is clear, however, from the discussion, that the author believes in at least a bi-fold division of the glacial formations of sufficient importance to allow each to be assigned to a separate epoch. It is also clear that he is hospitable to a threefold division each with the rank of an epoch, and the way is left open for recognition of a fourth.

In this connection Professor Chamberlin makes some suggestions of general interest concerning the subdivisions of the drift. He says:

> "If the ice age consisted of distinct glaciations separated by climatic conditions as genial as those of today, they might as properly be called periods as epochs of glaciation. If the intervals of ice retreat, whether they amounted to complete disappearances or not, were comparable to the post-glacial period in duration, in the amount of erosion, weathering, soil production, vegetal accumulation, orographic movement, or other work done, or in the geniality of their climate or the character of their life, they are surely entitled to be recognized as marking epochs. If the intervals fall notably short of this, it is doubtless best to regard them as marking episodes, rather than epochs. The need for recognizing them would still remain, however, if we are to decipher and delineate the intimate history of the Ice Age."

We suspect that many glacialists would not be willing to follow the above suggestion in full. We suspect that many of them would hold that an interval of deglaciation might fall "notably" short of the post-glacial interval, and still the re-advance of the ice constitute a separate glacial epoch, especially if the retreat and the subsequent re-advance of the ice were very considerable. If, for example, the ice retreated so far from its extreme position as to free the territory of the United States, and if, during this retreat, the region freed became temperate, a subsequent advance of the ice to the limit of the East Iowan formation might perhaps not improperly be regarded as a distinct glacial epoch, even if the deglaciation interval were notably shorter than the post-glacial epoch. Especially would this be true, if the ice remained long in retreat, and if other events, such as changes of continental attitude, intervened. Even on the basis which Professor Chamberlin has proposed, there is in the minds of many geologists no doubt but that at least two, and very likely three distinct glacial epochs have affected the North American continent.

Professor Chamberlin very properly insists that just at present it is a matter of subordinate importance whether the several divisions of the ice period be called epochs or episodes; that the thing which is impor-

tant is the recognition of the complexity and the protracted character of the glacial period as a whole. Until this is recognized, it will be difficult to prosecute work intelligently along the lines which must ultimately determine whether the rank of the several subdivisions is epochal or episodal.

A single word may be added with reference to Professor Geikie's chapter concerning the "Cause of the Glacial Climate." It has already been noted that the discussion of this subject has been relegated to the last chapter of the volume. In the course of this discussion it is evident that Professor Geikie holds much less strongly than heretofore to Croll's hypothesis of glacial climate. While he indicates that this hypothesis probably "contains a large element of truth" he does not regard it as a full solution of the vexed question. He further indicates that the complex phenomena of Europe "are evidence of a succession of changes too manifold, and perhaps occupying too short a space of time, to be accounted for by the cause to which Croll appealed." Professor Geikie's attitude seems to be well expressed in one of his closing sentences: "The primary cause of those remarkable changes is thus an extremely perplexing question, and it must be confessed that a complete solution of the problem has not yet been found."

ROLLIN D. SALISBURY.

Papers and Notes on the Glacial Geology of Great Britain and Ireland. By the late HENRY CARVILL LEWIS. Edited from his unpublished MSS., with an introduction, by HENRY W. CROSSKEY. Pp. lxxxi+469. Maps x., figures 83. London: Longmans, Green & Co., 1894.

Dr. Crosskey and the devoted wife of the late Professor Henry Carvill Lewis have placed all who are interested in glacial phenomena under lasting obligations by the publication, in elegant form, of the papers and notes of one who was among the most active and enthusiastic of American glacialists. It would have been a pleasure to the writer to have made earlier notice of this work, had not his absence from the country prevented. The book embraces papers on (1) Comparative Studies upon the Glaciation of North America, Great Britain and Ireland; (2) The Terminal Moraines of the Great Glaciers of England; (3) On some Important Extra-Morainic Lakes in Central England, North America, and elsewhere, during the period of maxi-

mum glaciation, and on the Origin of Extra-Morainic Bowlder Clay; (4) The Supposed Threefold Division of the Drift; (5) The Direction of Glaciation as ascertained by the Form of the Striæ; (6) Notes of observations made in the field, with their associated references, and with maps of routes and of the glaciated areas; (7) Memoranda and Brief Essays on various subjects connected with Glacial Geology; and, as appendices, (A) Extracts from the MSS. of Mr. Percy F. Kendall, and (B) Field Notes in Switzerland, Italy, South Germany, Belgium, and Holland. These papers and notes are presented as nearly in the form in which they were left by Professor Lewis as could be done consistently with a proper preparation for the press, Dr. Crosskey believing that this was both wiser and more loyal to his friend than any essential revision would be.

A peculiar interest attaches to the field notes of Professor Lewis, as they are thus frankly presented to us, because they open without reserve the door to his inner thoughts and impressions as they arose from day to day in the course of his rapid contact with new phenomena. We are permitted to see the advances, the oscillations and the occasional retreats of conviction that marked the application of his dominant working hypothesis to the problems he had undertaken. All who have had like experiences of oscillating conviction—and who has not—will find a sympathetic chord touched in the perusal of these notes.

Professor Lewis' method was distinctively that of the working hypothesis. While he entertained many supplementary hypotheses, and was by no means negligent of opposing hypotheses, there was one that was dominant and guided his work. The distributive affection that characterizes the system of multiple working hypotheses finds little expression in his investigations. With a strong faith in his chosen method, he sought to disentangle the intricate drift deposits of the British Isles by its energetic application. His working hypothesis sprang from his previous studies. During the decade preceding his notable work on the moraine of Pennsylvania, certain of the now older students of the drift, east and west, had detected a series of terminal moraines that had been previously overlooked or neglected, and had inaugurated the morainic method of discriminating and delineating the stages of glacial history. In the east the chief terminal moraine lay near the limit of the drift and was, for the time, supposed to be essentially coincident with it; in the west the chief moraines

lay at some distance back from the drift margin, and were not supposed to represent the full extent of the ice advance except locally, although correlated with those of the east. At the east, by virtue of the near coincidence of the moraine with the border of the drift, the word "terminal" came to have a double significance, in which *terminal to the drift* grew to be more prominent than *terminal to the ice* that formed it. It is needless to say that the latter is the original and true sense of the term, and that up to this time it had been employed almost exclusively in this sense in its application to the moraines of the Alps and elsewhere. Almost none of the previously recognized terminal moraines were marginal to the glacial deposits. The strength and definiteness of the outer terminal moraine in the Atlantic region, and the inconspicuousness of the drift outside it—which was almost overlooked for the time—naturally brought into great prominence the marginal position of the moraine, and fostered the development of the imported sense of the word "terminal." More than this, it led to the conviction that such a moraine was *characteristic* of the outer border of the glacial drift, if, indeed, it was not a necessary feature, and that by seizing upon it, and following it persistently, the precise limit of the ice advance might be definitely traced out and the true glacial drift distinguished from outlying drift transported by other agencies. It was this view, thus derived, that stimulated and directed the work of Professor Lewis in Great Britain and Ireland. His supreme effort was to detect and trace across the British Isles a moraine marginal to the true glacial drift, and to distinguish from this the outlying deposits which he believed to be formed by means other than direct glacier action.

The book sets forth by maps and clear descriptions the course of the moraine as traced by Professor Lewis, and also the nature and extent of the glacial movements that gave rise to it. It also presents the distribution of the marginal waters in Great Britain, by whose agency, in Professor Lewis' judgment, the extra-morainic drift was chiefly deposited. These were, in his opinion, mainly fresh waters, ponded back into lakes by the glacial obstruction of valleys and basins sloping *toward* the ice. He was led to very moderate views respecting the marine submergence of the land.

It must be left to British glacialists to say how far the delineations of Professor Lewis are likely to stand, but without doubt the introduction of the morainic method, and the definite mapping which he pre-

sented, must be regarded as a very stimulative contribution. The writer of this note does not agree with him in the belief that the *border* of the glacial drift is necessarily any more amenable to the morainic method than other portions; indeed, we think that European as well as American experience has already shown that it happens to be less so, as a major fact. The moraine-developing habit was most pronounced during the later part of the glacial period. More than this, we think it has been amply demonstrated that the border of the drift was formed at different times, and that the moraines that are marginal to it in one portion depart widely from it in other portions, one moraine lying on the border in one region, and another in another region, and that along a large portion of the border there is no conspicuous ridging of the drift. Nevertheless it is valuable to trace out any terminal moraine, whether it borders the drift or whether it separates drifts older from drifts younger, for it becomes, in any case, if successfully done, a tangible datum line for correlation.

Professor Lewis came to recognize, so far as England is concerned, that there was an earlier drift outside the moraine he mapped. Concerning this he says, p. 69 (*Postscript added to abstract printed in "Geological Magazine," November, 1887, p. 516*): "Since the paper [Extra-Morainic Lakes of England] was read of which the above is an abstract, I have found traces of the existence of a very much older series of glaciers than those here described.

"Since the period of these ancient glaciers, which in many places were more extensive than the modern ones, earth movements have occurred and erosion has removed almost all their deposits, and generally obliterated striæ, so that the region subject only to the older glaciation now resembles a non-glaciated area.

"The glaciers and their bordering lakes, described above should therefore be considered as belonging to the second or last glacial epoch."

And again, p. 390: "Recently I had found in the 'fringe' region of England evidence of a much more ancient glaciation; so old indeed that erosion had removed almost all the deposit and obliterated the striæ. Perched erratics occur above any possible lake. Is not this still due to an old glacier, and the red clay to an extra-morainic lake? Are they contemporary deposits? I find that the glaciers of the first epoch came from more southern centres than those of the second ice period."

T. C. CHAMBERLIN.

The Colorado Formation and its Invertebrate Fauna. By T. W. STANTON. Bull. U. S. Geol. Surv., No. 106, 288 pp., 45 plates. Washington, 1893.

In the preparation of this memoir the author has made extensive field studies in Colorado and Utah, and has had the benefit of certain unpublished notes by Mr. Walcott on the Kanab valley. In addition a careful review of previous papers and collections has been made with the satisfactory result that, whereas previously but twenty-five or thirty species had been definitely referred to the Colorado formation, one hundred and fifty are now listed. The greater portion of these, including some thirty-nine new forms, are described in this paper.

The history and definition of the Colorado formation is introduced by Meek and Hayden's Upper Missouri section, which has so long been the starting point for all work on the interior Cretaceous. The evolution of this section from the original five numbered formations to the present form is briefly sketched.

The Cretaceous is considered by regions, beginning with Iowa, and continuing through Kansas, Upper Missouri region, Colorado, New Mexico, and Utah. The portion devoted to Colorado and Utah is particularly full and interesting.

The Colorado fauna is compared with those of other marine Cretaceous formations. There are fourteen identical or very closely related forms which occur in both the Colorado and Montana. The Eagle Ford shales contain twelve typical Colorado forms, and the Austin limestone thirteen. Seven species are found in British America, and eight in Manitoba. A comparison with European formations shows the relations to be closest with the Turonian.

The species described are well figured, and the descriptions clear and concise. A large number of changes in nomenclature are made, many of which result from the changes in classification adopted by recent European writers. Few of the changes made will be more widely noticed than that of *Inoceramus problematicus* Schlot, the best known and most widely distributed Colorado form, to *Inoceramus labiatus*, a form described earlier (1813) by the same author. Another of the changes which deserves notice is the recognition of the western forms hitherto known as *Gryphæa pitcheri* Morton as belonging to an independent species which is christened *newberryi*. Still another change of importance is the recognition of Meek's American species

Prionocyclus woolgari as identical with the European form described by Mantell, now known as *Prinotropis woolgari.*

The bulletin shows a very happy combination of stratigraphic and palæontologic work. It will be welcomed by all students of the interior Cretaceous as a valuable aid. H. F. BAIN.

Analytical Abstracts of Current Literature.

The Relation Between Baseleveling and Organic Evolution. By J. B. Woodworth. (American Geologist, October, 1894, Vol. XIV., No. 4, pp. 209–234.)

In the historical sketch the writer speaks of the former strong belief of the British geologists in marine action as the origin of baseleveling, due in large measure to their insular position. They have recently been awakened by the work of the continental geologists in regard to baseleveling by meteoric agents.

In America, Powell, Gilbert, Davis, McGee, and others have established a cycle of existence for rivers and their valleys, ranging from youth, in a newly elevated country, through adolescence, maturity, and so on into old age, when, the land remaining stable, a peneplain will be formed. An uplift will revive the streams and start a new cycle. Many other points of interest are brought out by these writers in regard to the history of river systems.

Under the general effect of river changes on fluvial faunas, the important relation of the topographic history to the distribution of fresh-water fish and mollusks is shown. This may be through (1) head-water division, (2) antecedent streams, (3) alluviation, (4) slight submergence, (5) elevation and revival of streams.

Effect of baseleveling of a mountainous region is discussed, including the fading away of divides, the degradation of uplands, spread of lowland conditions, the peneplain as an open field for land life, uplift and dissection of the peneplain. The Jura-Cretaceous peneplain is discussed at length, both in its topography and its influence on life. It forms a conspicuous topographic feature in eastern North America, and traces of it occur on the Pacific coast. It is well developed in New England, Middle Atlantic states, and southward. At the close of the Cretaceous the peneplain was elevated when streams began to cut valleys, and another Tertiary baselevel had almost been completed when a new uplift caused rejuvenation.

The influence of the peneplain on life is most pronounced, being most favorable for reptiles, which abound in such great numbers. Reptiles are characteristic lowland forms. They can endure the cold of high altitudes or latitudes only by falling into a torpor. The conditions being so favorable, they thrive in such vast numbers and are of such great size that the mammals are virtually driven to the uplands and almost extinguished. Several theories

are advanced for the extinction of these large reptiles. Professor Verril regards lack of parental care as a cause; Professor Marsh thinks the small brain, highly specialized characters, and huge bulk, prevented them from adapting themselves to changing conditions. Wood attempts an explanation in the geographic changes. The flora, it is shown, changed almost as much as the fauna.

In attempting to extend his theories to periods of baseleveling antecedent to the Mesozoic, the writer finds a check in the insufficiency of knowledge concerning the early land forms. Comparison of meteoric baseleveling with glaciation and submergence shows that only the first is conducive to land life, that both glaciation and marine invasion are sterilizing in their effects.

T. C. H.

Tertiary and Early Quaternary Baseleveling in Minnesota, Manitoba, and Northwestward. By W. UPHAM. (American Geologist, Vol. XIV., No. 4, October, 1894.)

This paper forms an excellent supplement to the preceding one, taking up the history where the other leaves off. The area, character, vertical extent, etc., of the baseleveling of the northwestern plains during the Tertiary area is followed by a discussion of the renewed elevation and partial baseleveling at the close of the Tertiary. Attempt is made to correlate this period of leveling with one in Pennsylvania, New Jersey, the southern states, and in the West. The origin of the Red River valley is found in this later erosion. Topographic features of Minnesota and Manitoba, due to the cycles of baseleveling, are discussed, also the direction of the Tertiary and early Quaternary drainage. The last uplift, that at the beginning of Quaternary times, he says, raised the area 3000 to 5000 feet higher than it is now, as shown by the fjords and submarine valleys of the North Atlantic, Arctic, and North Pacific coasts. It was the culmination of this uplift that brought the great snow accumulations of the glacial period, under whose weight the land sunk below its present level, causing the ice to melt. His approximate measures of the denudation, along with some of his former estimates, give the duration for different periods as follows: Tertiary, two to four million years; the Lafayette, 60,000 to 120,000 years; Glacial period, 20,000 to 30,000 years; and the Recent period, 6,000 to 10,000 years.

T. C. H.

Proof of the Presence of Organisms in Pre-Cambrian Strata. MR. L. CAYEUX. (Bull. de la Soc. Geol. de France, Ser 3*e*, tom 22*e*, June, 1894, pp. 197–228.)

Stratigraphy.—Radiolaria occur in beds of siliceous schists (phtanite of Haüy) and quartzites of North Belgium, the position of which has been determined by Professor Charles Barrois. Their horizon is shown to be constant

in a series of schists and graywacke corresponding in point of ages with the *phyllades de Saint Lô* (pre-Cambrian).

Preservation.—The radiolaria were, as is usual with the Palæozoic forms, very badly preserved, so that a great many sections were necessary to obtain a few good specimens. Even these were so delicate and so surrounded and filled with fragments of carbonaceous material as to greatly increase the difficulty of observation. The outlines and details of structure were nevertheless, as the plates indicate, so complete in many instances as to leave no doubt as to the nature of the organisms. The skeletal silica is often found in the form of opal, often replaced by carbon.

Forms found.—Among the number of forms whose generic place could be determined beyond doubt are mentioned: Cenosphæra, Carposphæra, Xiphosphæra, Stanrosphæra, Acanthosphæra, Cenellepsis, Spongurus, Tripocalpis, Tripilidium, Tripodiscium, Archicorys, Cyrtocalpis, Dictyocephalus, Sethocapsa, Dicolocapsa, Theocampe; representing the sub-orders, Sphæroidea, Cyrtoidea, Prunoidea and (not determinable as to genus) Discoidea.

Criticisms.—The author takes up in detail objections that have been raised against the existence of radiolaria in pre-Cambrian strata as (1) the invisibility of the reticulated, skeletal structure, (2) the impossibility of seeing the siliceous tests imbedded in quartzite, (3) the uniform regularity of the figures observed and the size of the observed forms in comparison with known radiolaria, (4) the contact or intergrowth of the pre-Cambrian forms, (5) their similarity to foraminifera.

Character of the fauna.—A discussion of the grouping and comparative abundance of various species follows, and then a comparison of the pre-Cambrian fauna with the radiolaria of the Silurian and of the present. E. C. Q.

The Niobrara Chalk. By SAMUEL CALVIN, Iowa City, Iowa. (American Geologist, September, 1894.)

The presence of the Niobrara chalk has been demonstrated at various points in Iowa as far east as Auburn, in Sac county, while fossils in the drift indicate its former existence at points much farther east than this. The paper deals chiefly with the characteristics of the formation as exhibited eastward from the mouth of the river from which it takes its name. In their typical development the strata are soft, calcareous deposits lying in massive beds, and exhibit all the characteristics of chalk. The beds represent the final stage in a progressive subsidence, when the mechanical sediments gave place to those of organo-chemical origin, with waters clear and moderately deep, and the shore line probably a hundred miles to the eastward. An upward movement began before the close of the Niobrara age. The most conspicuous invertebrates are *Inoceramus problematicus* and *Ostrea congesta*. Numer-

ous citations are given showing that the general attitude of American geologists has been against the recognition of chalk in the American Cretaceous.

"The characteristics of the Niobrara chalk are such that exhaustive investigations with the microscope may be carried out with very little difficulty." Foraminifera are abundant, and in places constitute from one fourth to one third the volume of the chalk. Coccoliths are most abundant, though the small, rodlike rhabdoliths may also be detected with a high-power objective. The genera and species represented vary somewhat with the locality and the beds from which they were obtained. *Textularia globosa* is represented by a large and a small form, which grade into each other. The latter has been regarded as a distinct species, *Textularia pygmæa*, by Dawson. Differences in development are correlated with the probable conditions relative to depth and the amount of earthy sediments. The identity of the Niobrara with the English chalk is well established. C. H. G.

A Study of the Cherts of Missouri. E. O. Hovey. (American Journal of Science, November, 1894, p. 401.)

Thirty-eight specimens from different parts of the state were examined in fifty thin sections, about one-half from the Lower Magnesian (Ozark of Broadhead) Series, and about one-half from the Lower Carboniferous.

Petrography and fossil remains.—The cherts consist mostly of chalcedony, with quartz and opal present to some extent. Careful search failed to reveal any indication of radiolaria or sponge spicules, with the exception of certain slender, cylindrical rods in one specimen, which showed nuclei of a brown substance surrounded by clear chalcedony. Many of the fossiliferous cherts from the Lower Carboniferous showed sections of brachiopods, crinoids, and corals, and in some cases of Stromatopora.

Chemistry.—Analyses showed the non-fossiliferous cherts to be nearly pure silica with more or less alumina and iron. The "altered" and "unaltered" cherts are shown to be chemically very nearly identical. The very small percentage of water in the pure cherts would indicate a small amount of opal.

Origin.—The theories of Prestwich, Hull, and Hardman, Irving and Van Hise, Renard and Hinde are reviewed, and the author concludes that the cherts studied by him "are due to chemical precipitation, probably at the time of the deposition of the strata in which they occur, or before their consolidation." E. C. Q.

Recent Publications.

—Blake, William P.

Notes on the Structure of the Franklinite and Zinc Ore Beds of Sussex County, New Jersey. 4 pp.—From the Trans. of the Am. Institute of Mining Engineers.

—Call, R. Ellsworth.

A Contribution to a Knowledge of Indiana Mollusca. 43 pp.—From Proc. Ind. Academy of Sci., Vol. III., 1893.

—Darton, N. H.

Artesian Well Prospects in Eastern Virginia, Maryland, and Delaware. 26 pp., 2 plates.

—Dawson, George M., C.M.G., LL.D., F.R.S., F.G.S.

The Progress and Trend of Scientific Investigation in Canada—Presidential Address for 1894.—Royal Soc. of Canada.

—Geological Surveys:

Arkansas—J. C. Branner, State Geologist.

An. Rep., 1891, Vol. II., Miscellaneous Reports: Benton County, by F. W. Simonds and T. C. Hopkins; Elevations, by J. C. Branner; Observations on Erosion above Little Rock, by J. C. Branner; Magnetic Observations, by J. C. Branner; Mollusca, by F. A. Sampson; Myriopoda, by C. H. Bollman; Fishes, by Seth E. Meek; Dallas County, by C. E. Siebenthal; Bibliography of the Geology of Arkansas, by J. C. Branner. 349 pp.; illustrated; 2 maps. An. Rep., 1892, Vol. II., Tertiary, G. D. Harris. 207 pp.; illustrated; 1 map.

Minnesota—N. H. Winchell, State Geologist.

Preliminary Report of Field Work during 1893 in Northwestern Minnesota. 40 pp.—Arthur Hugo Elftman. Part XII. of Twenty-second An. Rep.

Missouri—Arthur Winslow, State Geologist.

Coal Report—Sheet Report, No. 2 Bevier Sheet, Map and Sections, including portions of Macon, Randolph, and Chariton Counties, with Descriptive Report. 75 pp.—C. H. Gordon, Assistant Geologist.

Iron Mountain Sheet—Sheet Report, No. 3, Map and Sections—including portions of Iron, St. Francis, and Madison Counties, with Descriptive Report. 85 pp.—Erasmus Haworth and Frank L. Nason, Assistant Geologist.

Pennsylvania—J. P. Lesley, State Geologist.

Geological Maps of the State and of Schuylkill, Carbon, Huntington, Dauphin, Lebanon, Bucks, and Montgomery Counties, and of the Bituminous Collieries.

Topographical Maps of the Blue Mountain at Port Clinton, in two sheets; the South Mountain District, three sheets; and of Buck and Montgomery Counties.

South Australia.

Annual Report of the Government Geologist, for year ending June 30, 1894, with Maps. 26 pp., 3 Plates.

—KING, F. H.

Destructive Effects of Winds on Sandy Soils and Light, Sandy Loams, with Methods of Protection. Illustrated. 29 pp.—From Agricultural Bulletin, No. 42, University of Wisconsin.

—MERRIAM, J. C.

Ueber die Pythonomorphen der Kansas Kreide. 39 pp., 4 Plates.

—RUSSELL, ISRAEL C.

Alaska—Its Physical Geography. 20 pp. and Map.—From Scottish Geog. Mag., Vol. 10, August, 1894.

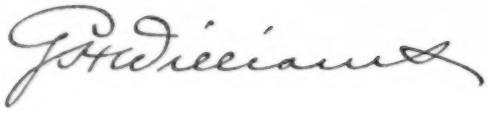
—SCUDDER, SAMUEL H.

The Effect of Glaciation, and of the Glacial Period, on the past Fauna of North America. 8 pp.—From Am. Jour. Sci., Vol. 48, Sept., 1894.

—THWAITES, REUBEN GOLD.

Early Lead Mining in Illinois and Wisconsin. 6 pp.—From An. Rep. Am. Historical Association, 1893.

—WARD, LESTER F.

Recent Discoveries of Cycadean Trunks in the Potomac Formations of Maryland. 9 pp.—From Bull. of Torrey Botanical Club, Vol. 21, No. 7, 1894.

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